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THE SOILS OF SOUTH-CENTRAL ONTARIO

L. J. Chapman and D. F. Putnam[1]

Ontario Research Foundation, Toronto, Ont.

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In a previous paper entitled "The Physiography of South-Central Ontario" (5) there was presented an account of the topographic form and nature of the geological material upon which the soils have been developed in that part of the province lying between Lake Ontario and the Pre-cambrian Shield and bounded on the west by the Niagara Escarpment from Hamilton to Collingwood. Such information is a necessary background for a description and classification of the soils in this region because of its complicated geological history and the comparatively youthful development of the soils themselves. For the most part the area has a deep covering of drift, the soft limestones and shales which constitute the underlying bedrock being a prolific source of material. The rough, hilly, sandy moraine running east and west through the centre, the rolling ground moraine with its attendant drumlins, the gravelly beaches, the sands and fine sands of the deltas and the level beds of silt and clay in the old lake bottoms provide the parent materials for an extremely variable and interesting group of soils. Thus, having clearly in mind the physiographic nature of the country, it is proposed in the present paper to proceed to a description of the outstanding soil characteristics, and to classify the chief land types.

PEDOLOGICAL FACTORS

It is an accepted fact that the character of the soil is influenced more by climate than by any other factor. Climate and the associated vegetation govern the type of leaching process which operates in any given region, and these factors largely govern the distribution of the major soil groups of the world. Locally, however, the important soil differences are the results of the depth, form and nature of the drift and the attendant drainage conditions.

That part of Ontario discussed herein lies in the podsolic zone, but the soils are largely grey-brown podsolic soils rather than mature podsols. In the more northerly and easterly sections, true podsols occur in sandy areas where drainage is imperfect but they are not extensive.

The geological material is especially important, in view of the highly calcareous nature of much of the drift, since it gives rise to "endodynamorphic" soils; that is, soils which are abnormally characterized by the parent material because of the degree to which it has resisted the processes of weathering. This is manifest in the large tracts of alkaline soil in which

[1] Research Fellows.

it is not uncommon for virgin soil in well-drained locations to have carbonates in the surface horizon, while, in the cultivated fields of over one-third of the area, free carbonates are present in the plowed layer. Some of the calcareous soils are poorly drained but most of them are well drained and have a good horizonal development with zones of eleuration and illeuration typical of the podsolic soils. It is perhaps worthy of note, that free carbonates are present in the A_1, but absent in the A_2 and B horizons.

While soils formed on such calcareous materials are in some respects related to the "Rendzina" group (2), their descriptions do not correspond in that they lack the deep, dark surface layer, and have the normal horizonal development. They are unusually alkaline soils to be found in a humid region such as this, and are looked upon by the authors as intrazonal members of the grey-brown podsolic soil group.

In the south-western part of the area, where the till contains a high proportion of shale; on the northern uplands of Simcoe county, where there is a predominance of Archaean material in the till; and in well drained sandy areas, generally, there are to be found acids oils with typical regional characteristics.

CLASSIFICATION

In the area under discussion there are between 35 and 40 distinct types which would be isolated, described and mapped in the course of a detailed soil survey. Some of them are well known types, previously described, since they occur in other parts of the province where detailed soil surveys have been made by the Department of Chemistry of the Ontario Agricultural College; but the majority are new or different. In this paper it is not proposed to describe the individual soil types, but rather to group similar types and to describe them under broader units as "land types," which, in the process of description, will be named according to their outstanding characteristics. From a taxonomic point of view, these soil divisions are somewhat similar to the land types and sub-types described by Veatch (7) in the State of Michigan. It is an arbitrary grouping of soil types which have similar profile characteristics, uses, values and crop adaptations.

Having, from observation in the field and from the results of chemical tests, obtained a survey of the chief characteristics of the soils throughout the area, the information for each factor has been placed on a separate chart in the following series. In this way, it is hoped that a graphical presentation of those factors which limit the use of land and affect its cultural treatment will be effectively achieved. Subsequent to the discussion of the physical and chemical characteristics, the land types will be described and their geographic distribution indicated.

For some purposes the ultimate soil type is none too fine a definition of soil character; but in certain ecological studies, such as variety testing, it is necessary for practical purposes to deal with groups of similar types. Furthermore, such treatment has the advantage of preventing a report of this sort from becoming unduly cumbersome.

Physical Characteristics

Of the factors which limit the use of land, the physical characteristics such as topography, depth to bedrock, texture and drainage are more influential than the chemical factors. Soil reaction and fertility levels are

certainly important, but the farmer can alter them to some extent as required. He must, however, plan his type of agriculture to fit the existing conditions of topography, texture, and other factors.

Topography

Because it limits the use of land, the proportion of an area which is too steep to permit of cultivation is of special interest; moreover, the degree of slope is important in relation to soil erosion. Figure 1 is a relief map of south-central Ontario indicating the chief topographic forms. An outstanding feature is the interlobate moraine, running through the centre of the area, on which there is a large proportion of land too steep for cultivation. There is considerable erosion on the steep hillsides, and as much of the soil is sandy, it tends to promote soil drifting.

In the drumlin belt, the topography, while quite rolling, generally permits cultivation although many of the larger and steeper hills have retained a strip of rough pasture or forest along their sides because of the slope. Such drumlins are most abundant in the counties of Peterboro and Northumberland. The more irregular hills of the limestone moraines also have much land which is too steep for cultivation.

On the south slope, facing Lake Ontario, and particularly in Durham county, the till plain is dissected at frequent intervals by abrupt gullies which interfere with cultivation. Incidentally, these gullies probably constitute the most definite erosion problem to be seen in any part of the area. The uplands of Simcoe county include some very steep hillsides, the old shore cliffs of Lakes Algonquin and Iroquois are usually too steep for cultivation, and finally, the Niagara Escarpment gives rise to a strip of rough, hilly land from Hamilton to Collingwood. It is probable that about 7 or 8% of the total area is too rough and steep for cultivation. The remainder, consisting of level lake plains, undulating ground moraine and rolling drumlins, constitutes ideal arable land.

Depth

The depth of the drift over the bedrock in various parts of the area is indicated in Figure 2. The limits imposed by extremely shallow soil such as that of the Napanee plain or the northern part of Victoria county are obvious. However, in the second division outlined on the map, where, although the bedrock only occasionally appears on the surface, it is, as a rule, covered with a rather shallow mantle of drift, the effect is, perhaps, not so well understood. It is here that shallow rock basins and blocked drainage channels cause so much of the area to be poorly drained or swampy; while a combination of factors, including stoniness and the presence of bedrock barriers make it difficult to instal tile drains.

Much the larger area consists of deeper drift in which drainage is not so restricted. Proper surface channels have been formed in most cases, and in the few cases where needed, artificial drains are comparatively easily installed. In the deeper drift there is also better internal drainage which allows the processes of weathering to take place more rapidly, resulting in a more advanced development of the soil.

Drainage

In Figure 3 is shown a survey of the general drainage conditions of the soils in the region. To a considerable degree, the drainage is governed

FIGURE 1. The chief topographic features of the area.

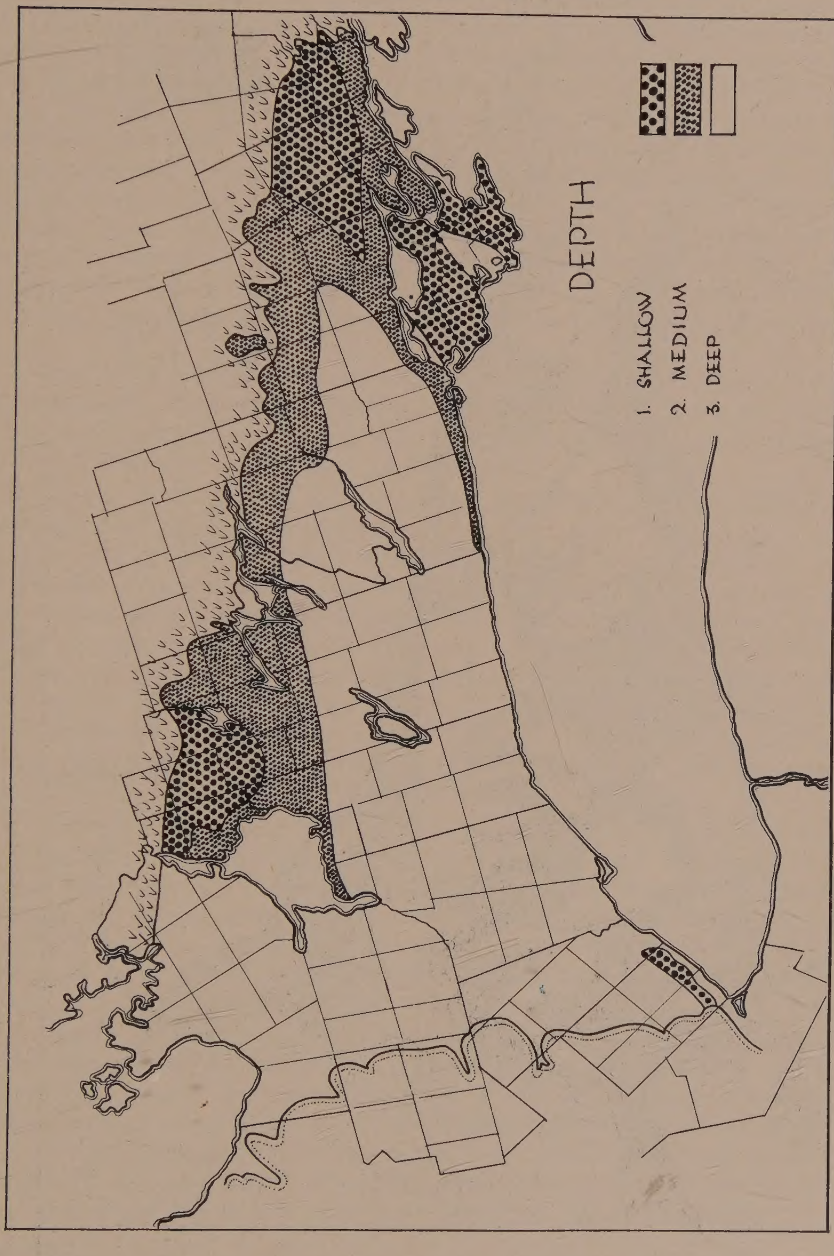

FIGURE 2. A general chart of the depth to bedrock.

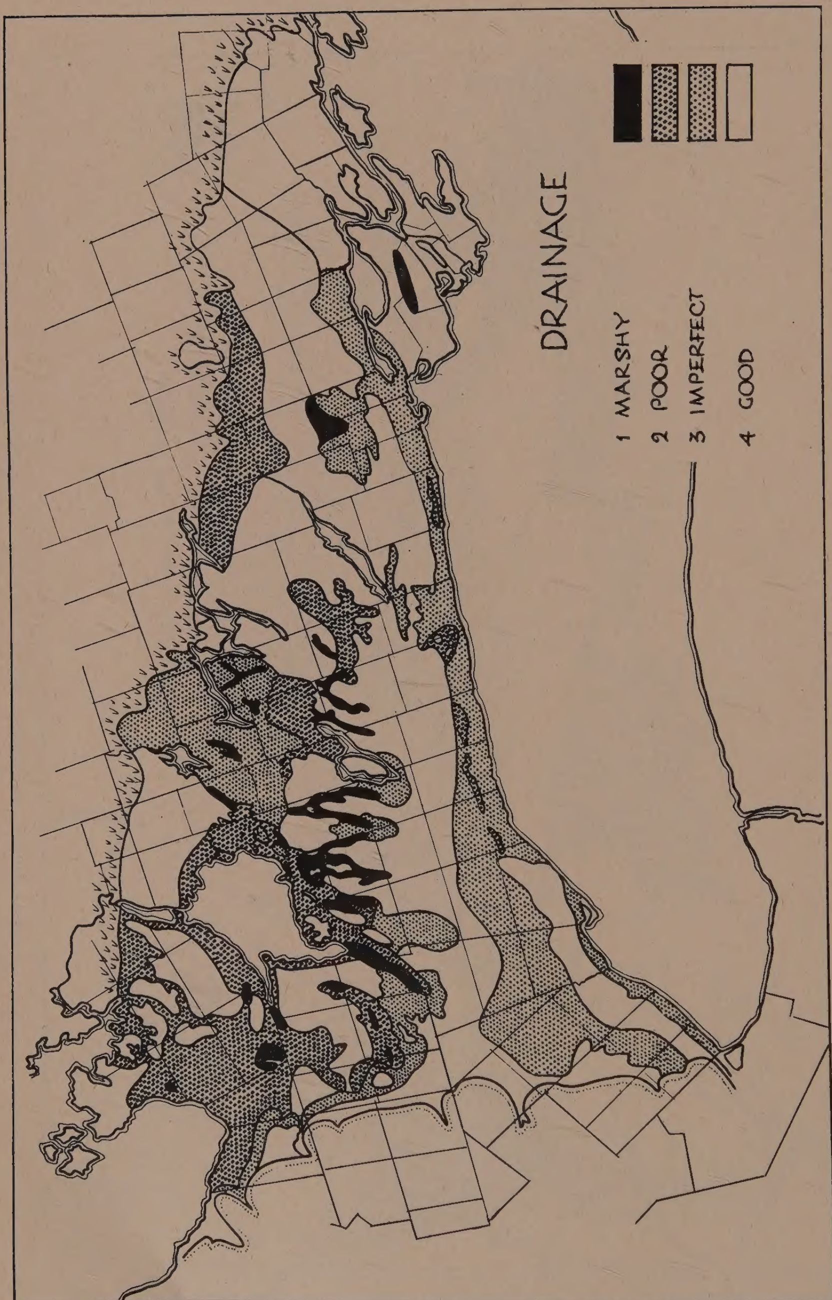

FIGURE 3. A general chart of drainage conditions.

by the topography, and it is generally considered that the greater the relief of an area, the better the drainage, but there are notable exceptions. In some level areas, as for instance, in the vicinities of Camp Borden and Alliston, there are deep sandy soils which have good vertical drainage. In the Peel plain there are heavy soils which are as well drained, although more nearly level than the rolling till soils adjacent. Both have similar clay subsoils, but the former have uniformly fine textured surface layers, while the latter class has a somewhat lighter, more gritty surface which becomes more readily waterlogged. In the southern part of Oro township there are rolling areas in which the soil has poor internal drainage, while a similar condition occurs in Darlington township where there is a light loam or sandy loam surface over a heavier subsoil. It is worth noting that as a rule those soils which are most uniform in texture throughout their profile possess the most desirable drainage conditions; whereas excessive textural differences are likely to interrupt the natural movement of water in the soil.

One of the commonest causes of poor or imperfect drainage is the presence of seepage from areas at higher elevations. Springy spots are common along the sides of many drumlins, a condition which it is almost impossible to correct effectively by means of tile drains.

Poorly drained areas are frequently encountered in association with the shorelines of the extinct lakes. There are many seepage areas at the foot of ancient shore cliffs. Where well-formed beach lines exist, there is usually a depression on the shorewood side, which receives and holds the run-off water from the higher land. "Boulder pavements", besides being very stony, are often also very wet. In the other hand, the beaches themselves, because of the coarse sand and gravel which they contain, are too well drained and often drouthy. For these reasons, a strip of waste land sometimes a mile or so in width, is found fairly consistently, just inside the Iroquois shoreline from Toronto to Trenton. Similar areas are found at many points along the shore of Lake Algonquin.

Those areas in which there is only a shallow mantle of drift overlying the bedrock are a mixture consisting of well-drained knolls and ridges either surrounded by or enclosing swamps of varying degree. Long narrow swamps are often found in the valleys of northward flowing streams. Drumlinized country also contains some narrow swampy basins lying between the hills. There are also marshy areas bordering many of the existing lakes.

Finally there is to be considered those extremely shallow soils which present conditions thwarting description on an ordinary chart. In many places the bedrock has enough relief to permit continuous free drainage, but over much of the more nearly level areas the soil may virtually be said to be at all times either too wet or too dry. With downward percolation prohibited, the few inches of soil readily become saturated during a rain, but with equal rapidity it again becomes dried out and parched.

Texture

The prevailing texture of the surface soil is shown in Figure 4. A map of such small scale of necessity includes very little detail and it is therefore expedient to point out some of the features which cannot be graphically expressed. The areas of coarse sands actually include inliers

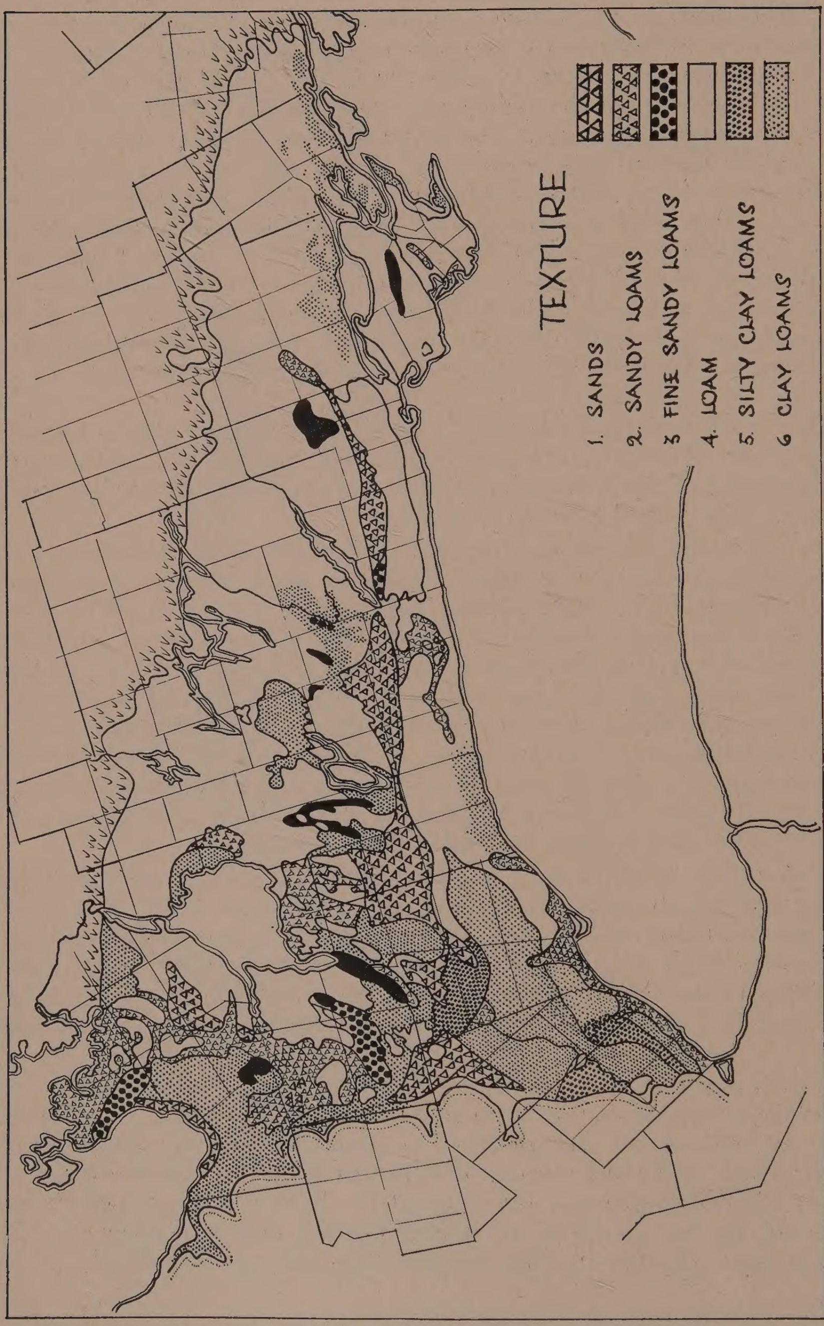

FIGURE 4. A general chart of the texture of the surface soil.

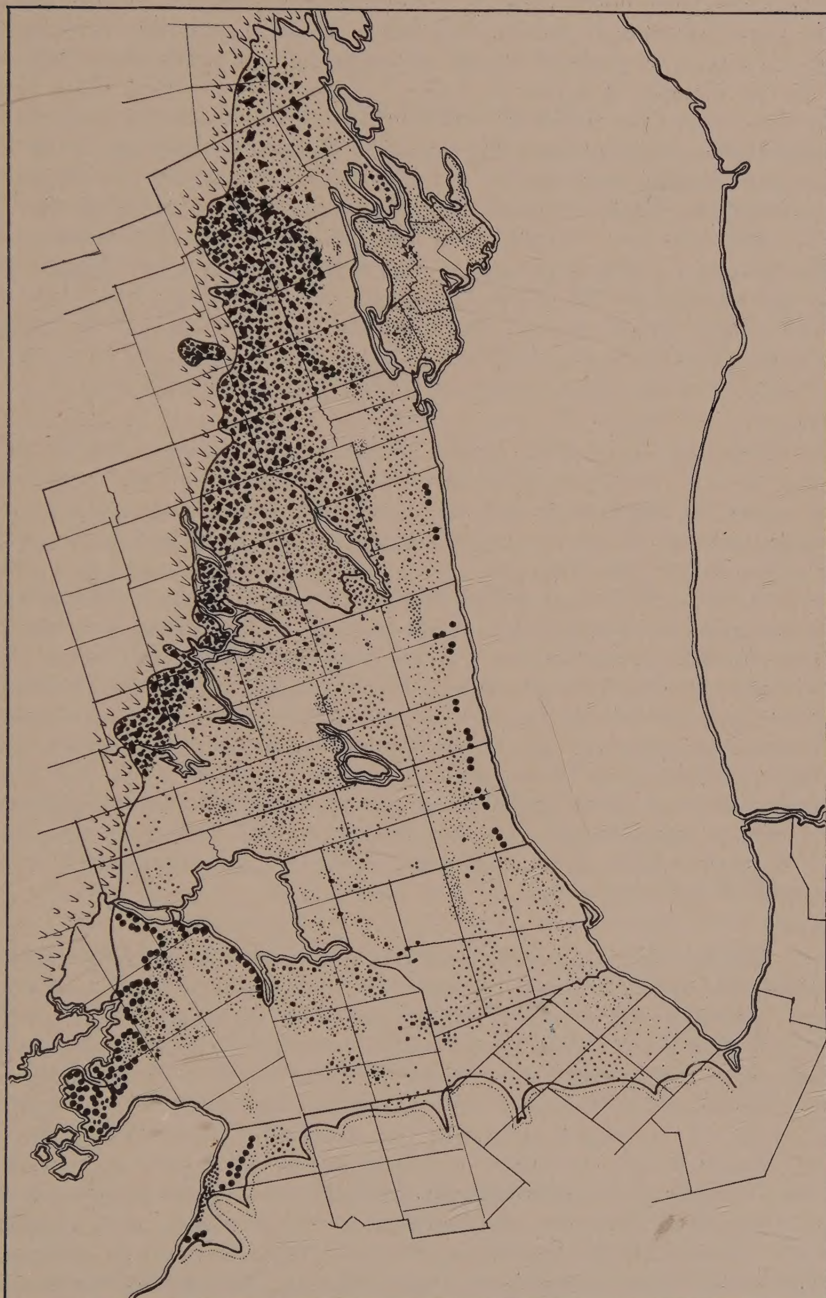

FIGURE 5. A chart of the relative stoniness of the soil

of sandy loams and fine sandy loams as well as occasional knobs of clay. In north Simcoe the soil on the uplands is classed as a loam, although in actuality it becomes more sandy as one proceeds northward, so that much of it is a very light loam. Similarly in Victoria county, the soil varies from a stony clay loam in parts of Mariposa township to a sandy loam farther north in the vicinity of Cameron Lake. The soil in the Peel Plain is a heavier clay loam than is the till soil common to Chinguaconsy township. In the Iroquois plain between Toronto and Hamilton there are areas of clay loam, especially some heavy red clay near Burlington, but the predominant soils are sandy loams developed on the old Iroquois deltas of the streams which now flow through them into Lake Ontario. The sandy and gravelly soils of the old beach deposits of Lakes Iroquois and Algonquin are not represented on the chart; neither are the esker ridges which are so abundant in the broad area of loams in the drumlin belt. Both these features are the causes of important soil differences but since they exist as very narrow strips, they cannot be shown on a small-scale map.

Structure

By "structure" is understood the degree of compactness or of crumbiness, the physical condition of, rather than the size of the soil particles. In this regard the heavy soils are our main concern since the sandy loams are single-grained in structure, and the loams are usually friable and easily tilled. Clay loams, however, may vary widely in their structure. For instance, the clay loam in the Peel Plain to the east of the Credit River has an exceptionally good crumb structure, and in the spring it is particularly noticeable that this soil will be loose and crumby, whereas the adjacent acid clay loams on the shaley till will be much more compact and consequently more difficult to work into shape as a seed bed. A similar good structure is possessed by the calcareous clay loams of the Schomberg lake plain, while the heavy acid soils on the marine clays of the Napanee plain may have a physical condition as poor as that of the aforementioned shaley soils, or even worse. In the Algonquin lake bed there are also heavy clay soils which, because of poor drainage, may frequently have poor physical condition.

Stoniness

Any considerable number of stones in a soil detracts from its value, because of the obnoxious way in which they impede the process of cultivation, indeed, there are areas where excessive stoniness prevents the use of sites which otherwise possess very favourable soils. The relative stoniness in various parts of the region is shown in Fig. 5 in which there is an attempt made, by means of the number and size of the dots, to depict the character of the stones as well as the number present. The stoniest soils are found on the limestone moraines in the northeast, and on the "boulder pavements" along the shorelines of Lakes Algonquin and Iroquois. Irregular pieces of limestone are common to the moraines, and rounded Archaean boulders to the shorelines, but in both cases much of the land is left uncleared either as woods or rough pasture. The soil on the drumlins, especial in parts of Peterboro, Northumberland and Hastings, may be excessively stony although most of it is cleared where the topography is at all favourable. In the northern uplands of Simcoe county there are also some very stony places.

The lacustrine soils are generally quite free from stones although occasionally erratics occur. The soils developed on the ground moraine of the Ontario ice lobe are also fairly free from stones, the shaly group in York, Peel and Halton counties are particularly favoured because of the soft nature of the rocks from which the till was derived.

Chemical Characteristics

Having discussed the chief physical properties of these soils, it remains to describe the chemical characteristics. Since these involve the results of various soil tests the procedure and methods used are of interest and will therefore briefly be considered.

During the course of the field work a series of samples was taken from each of the more prevalent types of soil which were identified. In order that these samples might be representative of cultivated land which had received no special treatment they were usually taken from hay or pasture fields, although occasional samples were taken from grain fields. Actually about 75% of them came from alfalfa fields. A small proportion of the tests were made on freshly collected samples in the field but most of them were air-dried and later tested in the laboratory.

Soil reaction was obtained by the use of indicators, chiefly brom-thymol-blue and brom-cresol-green in their respective pH ranges. Carbonates were graded roughly according to the amount of effervescence produced by weak hydrochloric acid. The Spurway (Simplex) tests (6) were made for nitrates, phosphorus, potash, calcium and magnesium; easily replaceable potash was determined in a neutral, normal sodium chloride extract, shaking for five minutes but proceeding otherwise as in the Spurway system. It was found highly desirable to read the potash tests before a uniform white light against a shiny black background, using prepared standards for comparison. Easily replaceable calcium and magnesium were determined in the same extract and the data used to supplement the results of the Spurway tests. Finally, the easily soluble phosphorus was extracted with a $KHSO_4$ solution at a pH of 2.0 using a soil to solution ratio of 1 : 14, the phosphorus content being graded as in the Lamotte-Truog field tests (3). In all, over 750 samples were tested, 70 being from the most extensive type of soil encountered, and correspondingly fewer from those less important. The data obtained from these tests have been incorporated in a series of charts similar to those of the physical characteristics. In this way a general idea of the natural fertility levels in the various districts is obtained and may be used as a guide to lime requirements and fertilizer needs of the various soils. Figure 6 shows the locations from which the soil samples were collected.

Reaction

The first factor to be considered is reaction. Not only is it the best single index of lime requirement but it is correlated with many other properties that affect crop adaptation. The approximate pH values of the surface soil of cultivated fields in the various localities is indicated in Figure 7.

It has been stated already that the region contains an unusually large area of alkaline soil. The calcareous clay loams and the marly soils have a reaction above pH 8.0 which according to McGeorge (4) is the critical

FIGURE 6. Location of soil samples.

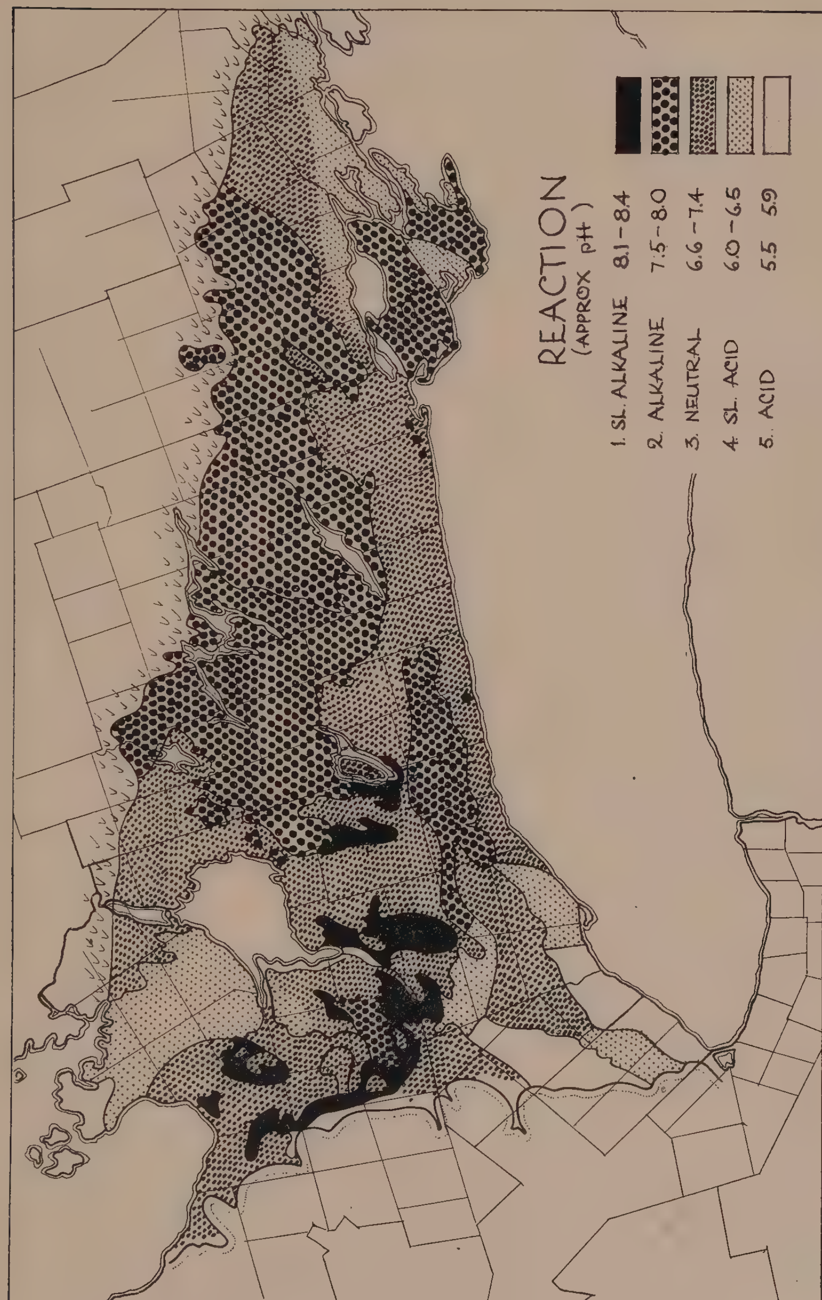

FIGURE 7. The reaction of the surface soil in cultivated fields.

limit for phosphate solubility in alkaline soils. The stony loams on the limestone till, and the calcareous, poorly drained, fine sandy loams have a reaction lying, for the most part, between pH 8.0 and pH 7.5, while there is a very large area of soils of various textures having a circumneutral reaction (pH 6.5–7.5). The area outlined on the map includes scattered areas of calcareous soil, such as eroded places which have a pH value above 7.5 and, on the other hand, many spots in the coarse sandy soils of the Interlobate area may have a reaction below pH 6.5. The clay loam in the Napanee plain, the light loam on the Simcoe uplands, and some of the mixed limestone and shale soils found chiefly in Scarboro and King townships are only mildly acid (pH 6.0–6.5). The most acid soils are those developed on the shaly drift in Peel and Halton counties, where most of the soils are about pH 5.5 while some samples possess values as low as 4.5.

Carbonates

Figure 8 is a map showing the incidence and relative amounts of free carbonates in the surface soil, as indicated by effervescence with dilute acid. Some of the free limestone now found in the plowed layer was present in the original surface horizon of the virgin soil, some of it is the result of erosion and washing, and the rest from plowing up the subsoil. Earthworm casts on the surface are sometimes highly calcareous. In the case of poorly drained soils, most of the carbonates were present in the virgin surface; in the case of the calcareous clay loams all the above factors may contribute; while in the case of the stony loams, perhaps most of the limestone has been plowed up owing to the shallowness of the profile.

The marly soils in Simcoe county near the Minesing Swamp and Marl Lake have a high carbonate content, the surface frequently having a white colour due to the presence of the marl. In the second class, where a strong effervescence with acid is indicated, the Schomberg clay loam is known to have a carbonate content of from 2 to 4% (expressed as $CaCO_3$ equivalents) in uneroded locations, while the soils of the third class will have lesser amounts. In the third class, carbonates are found only infrequently. All told, it will be seen that over one-third of the area is calcareous, somewhat less than a quarter has soil which is acid in reaction, while the remainder has soil which is nearly neutral in reaction and may or may not have traces of free carbonates on the surface.

Available Calcium

In Figure 9 are shown the levels of the easily soluble calcium in the surface soil. The available calcium is correlated with reaction modified by texture, heavy soils being better supplied than those of a more sandy nature having the same pH values. Hence the lowest levels are found in the sandy soils of the Interlobate area, although the reaction of most of the samples was near the neutral point. Similarly the sandy soils of the Algonquin plain are as low in available calcium as the loams of the Simcoe uplands or the much more acid clay loams in Halton County.

Available Magnesium

Magnesium is less abundant than calcium in the soil, and while in some instances, deficiencies occur demanding the use of dolomitic limestone, no definite cases of magnesium deficiency have been seen in this

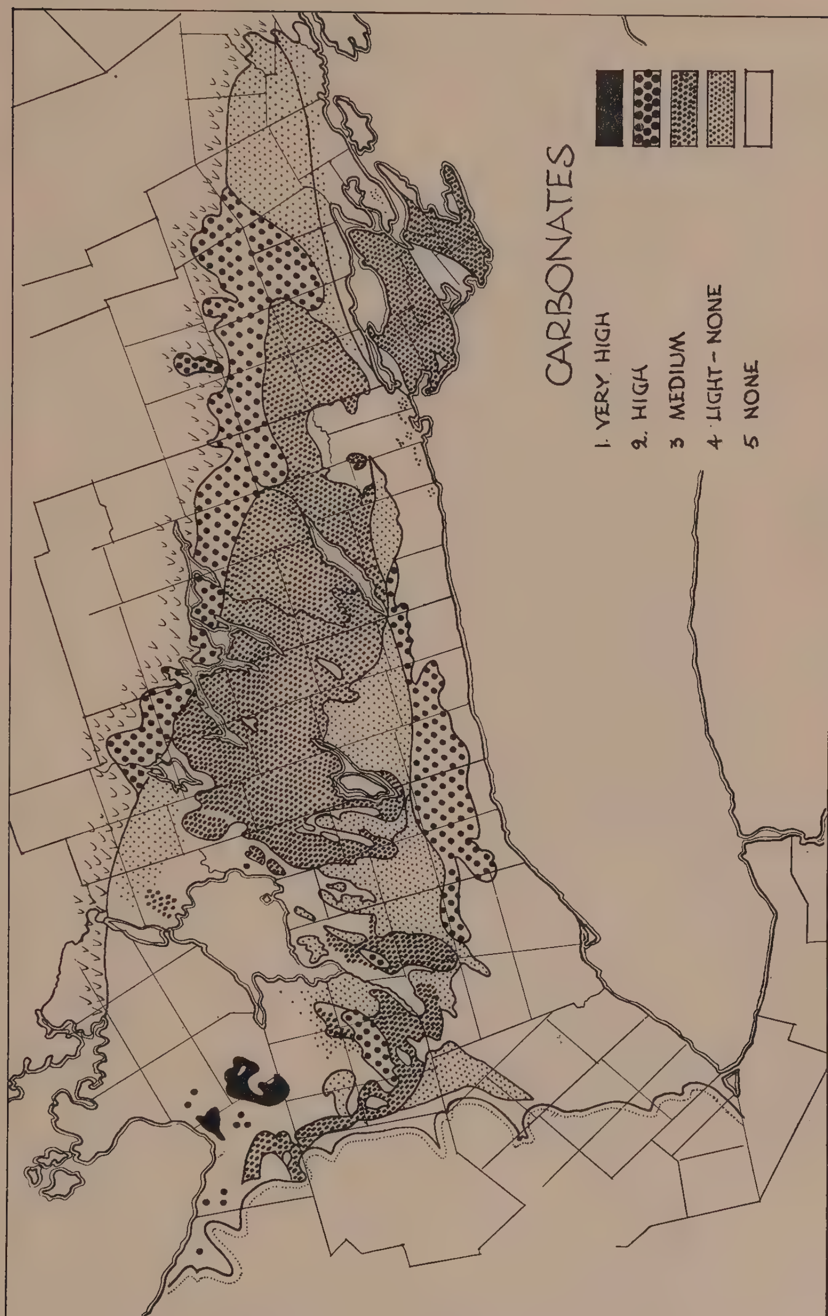

FIGURE 8. The relative amounts of free carbonates in the surface soil of cultivated fields.

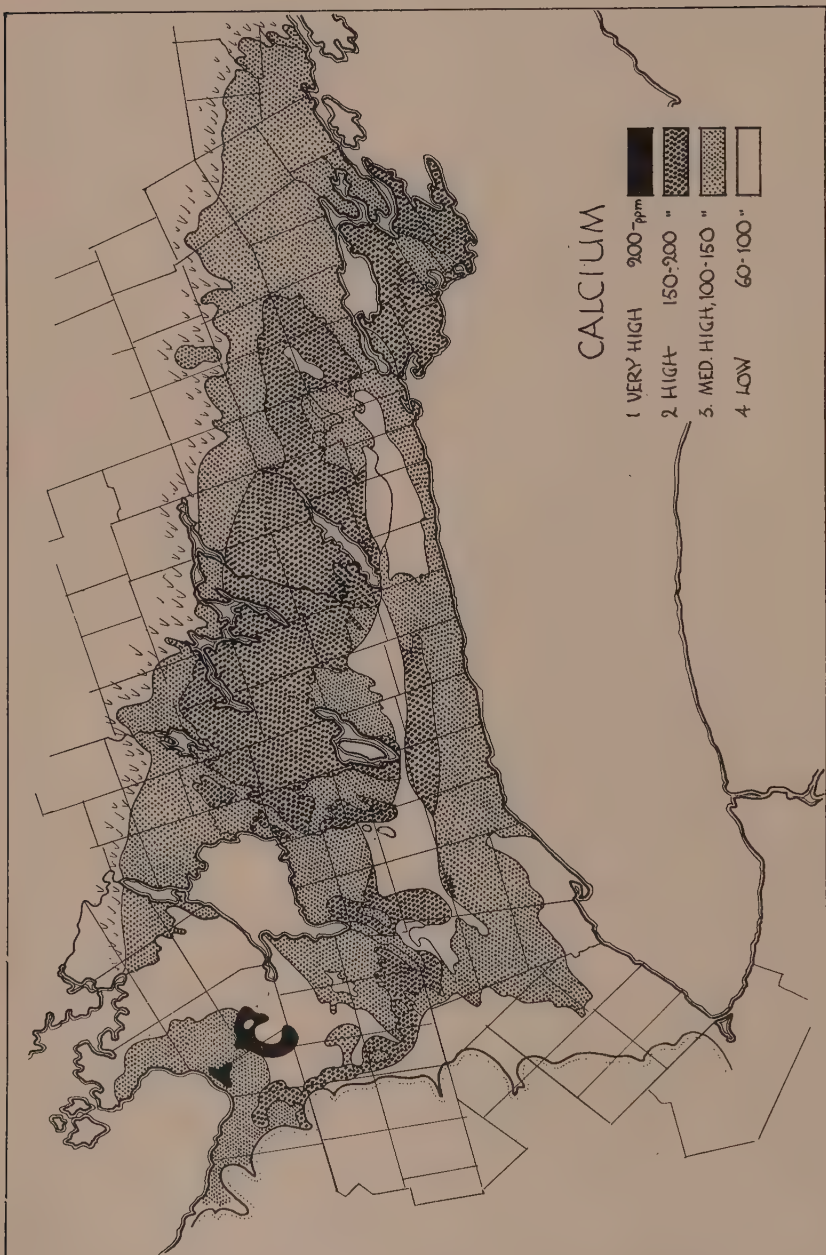

FIGURE 9. The easily soluble calcium levels in the soil.

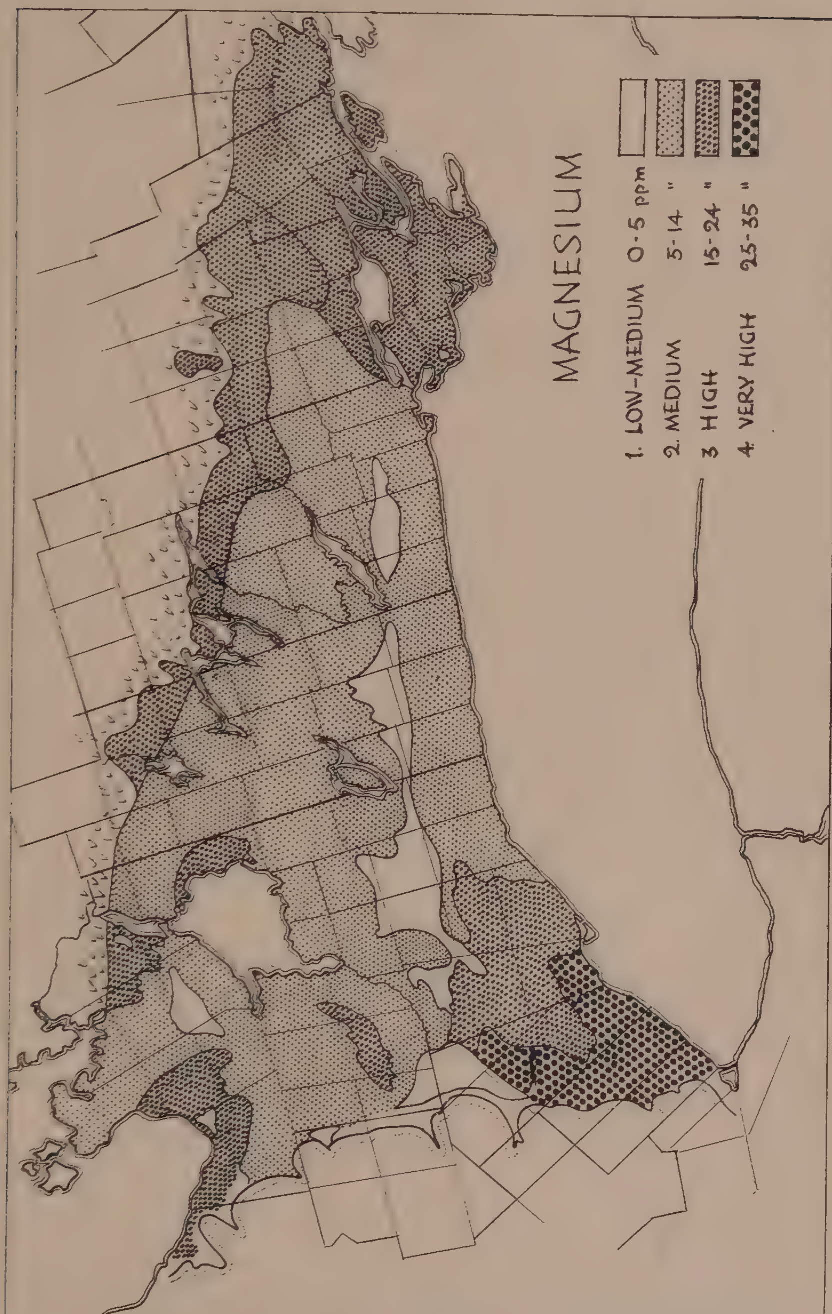

FIGURE 10. The easily replaceable magnesium levels in the soil.

region. However, the levels in some of the soils are quite low, and especially is this true of the sandy soils of the Interlobate area. It is a peculiar fact that the most acid group of soils, the shaly soils, have the highest content of available magnesium, much higher than that of the broad areas of calcareous soil. The low magnesium levels unquestionably reflect the calcitic nature of the parent limestones. Figure 10 shows the comparative distribution of easily replaceable magnesium in the soils of the region.

Available Nitrogen

The amount of nitrate nitrogen in a soil varies widely with the seasonal conditions and other factors such as uptake by growing crops; therefore a single test is of doubtful value as an index of the available nitrogen in a soil. Moreover, the degree of dark green colour in the foliage is so closely indicative of the supply available to the plant that it is not so necessary to test for this element. Therefore, although all the samples were tested for available nitrates, it has not been thought advisable to present the data in the form of a chart.

Available Phosphorus

It should be stated at the outset that, without exception, all the soils in south-central Ontario are low in available phosphorus. Nevertheless, there is considerable variation in this respect, and the soils have been classified into three divisions according to their relative levels, as shown in Figure 11. The data for this chart were obtained from the results of the $KHSO_4$ extraction method, although there was found to be a fair degree of correlation between it and the Spurway test.

In general it would seem that this element is most abundant in the sandy soils and more likely to be deficient in the heavy clays, but, beyond this, there seems to be an interesting correlation with geological material. The light loams and sandy loams of the northern part of Simcoe county, where the till is composed largely of Archaean materials, are quite deficient for soils of such texture and reaction. The shaly soils of Halton and Peel counties have the lowest supply of all. On the other hand, the heavy soil on the marine clay in the eastern section is fairly well supplied. While some of the very alkaline soils, above pH 8.00, particularly the calcareous clay loams, are deficient due to the lack of availability, the fact should be stressed that there are large tracts of fine sandy loams, loams and stony loams which have calcareous plow soils that contain average or better than average amounts of easily soluble phosphorus.

Available Potassium

The general distribution of the various levels of available potash is indicated in Figure 12. Here again there is a definite correlation with texture but the relationship is the reverse of that shown in the case of available phosphorus. The sandy soils, without exception among the samples tested, were low in potash; the loams tend to be in the medium class and the clay loams are well supplied. The influence of geological material is also evident: the loams derived from Archaean drift are higher in available potash than similar textured soils on the limestone till, while among the heavier soils, those developed on the shales are most abundantly supplied. In fact the shaly soils have the best supply of potash of any of the soils in the region.

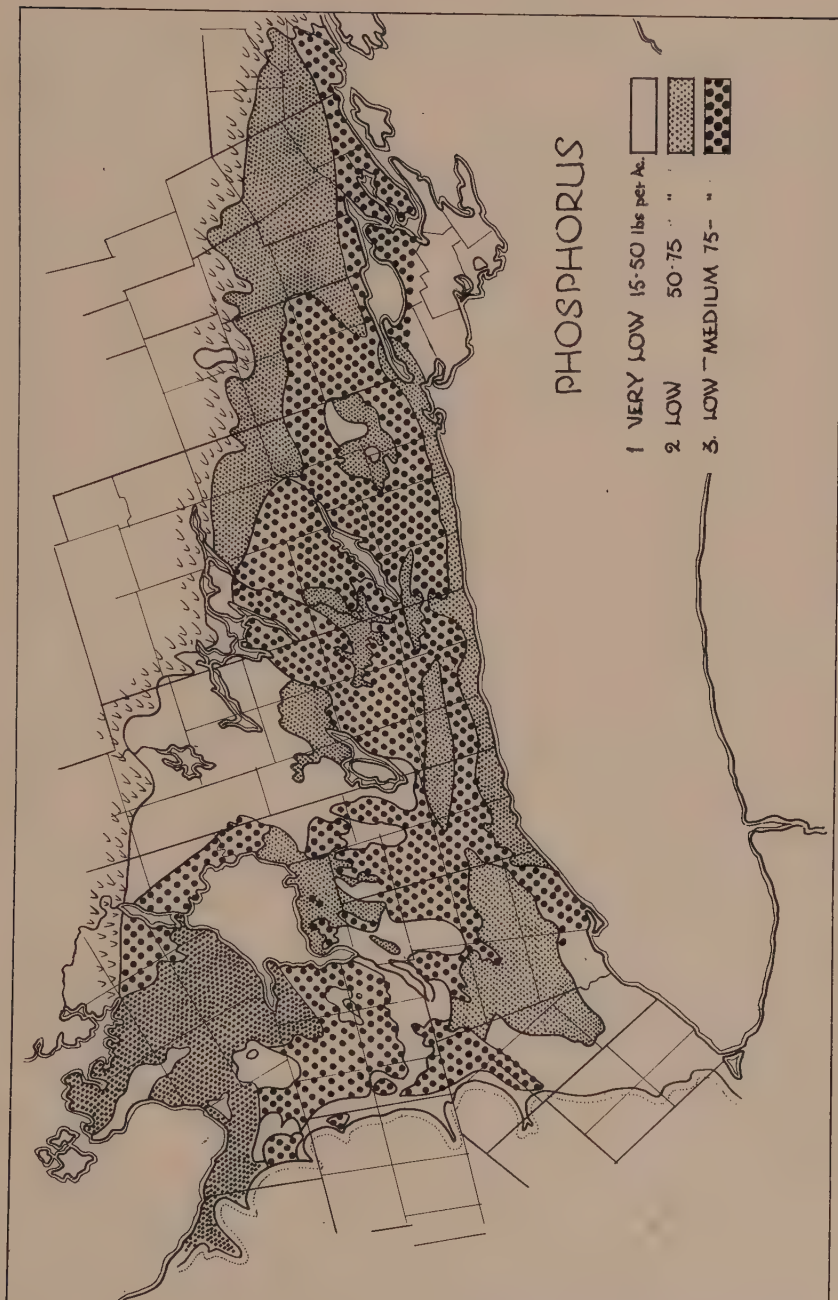

FIGURE 11. The relative amounts of available phosphorus in the soil.

Organic Matter

While at the present time there is not sufficient data available upon which to construct a chart of organic matter content, it is possible to point out some observed differences. Apart from the organic soils, which are fairly abundant, those with the highest organic matter content are the poorly drained, alkaline soils, which are found fairly extensively in the Algonquin Lake plain. The clay loam of the Peel plain is above the average in this respect, the organic horizon of the virgin soil being fairly thick. This is in sharp contrast to the adjacent shaley soils which had very thin surface horizons and consequently are quite low in organic matter. From general appearances it would seem that the soils with the lowest levels of organic matter are the sandy soils of the interlobate moraine and similar areas of coarse sand and gravel.

Fertilizer Requirements

The object in making soil tests for the various chemical constituents is, needless to say, to provide a basis for rational recommendations as to the fertilizer requirements of the various crops on the different soils. It is obvious that the day of blanket recommendations is long past, and while there is no substitute for properly controlled fertilizer tests with each crop to be grown to the various types of soil, it is felt that a survey of the natural fertility of the areas concerned should be a valuable aid both in the planning of such experiments and in the formulation of interim recommendations.

From the fact that alkaline and calcareous soils are found over so large an area it can be seen that in those areas, at least, there is no problem of lime requirement. In such cases the futility of adding more ground limestone is evident; moreover, because of its tendency to increase the pH to a point where soluble phosphates are converted to the carbonato-apatite form, which is relatively insoluble and hence unavailable to plants, it may even be detrimental. This is also true of the limestone used as filler in commercial fertilizers.

On the other hand, almost a quarter of the area is occupied by acid soils. Some of these soils produce good crops of alfalfa and clover without any special treatment probably because there is an abundance of lime in the subsoil at a comparatively shallow depth. Even though only mildly acid, and containing medium amounts of soluble calcium and magnesium, the soil on the marine clay responds markedly to liming, because it has a greater depth of acid soil and very little free carbonate in the subsoil. Most of the acid soils should respond to applications of ground limestone, either the calcitic or dolomitic type being suitable for heavy soils, but the dolomitic being preferable in the case of sandy soils.

Throughout the area phosphorus is required, and fertilizers having high amounts of phosphate should be used; in fact, in many cases superphosphate alone is the most economical commercial fertilizer to apply.

It is believed that the results of soil tests are a fairly reliable guide as to the widom of applying potassic fertilizers. Those soils which are in the lowest class (Figure 12) are definitely in need of potash, and symptoms of potash deficiency have been observed in certain crops grown in those areas; hence a high proportion of the element in question should be present in all fertilizer used. Those in the next class, having 20–30 p.p.m. in the

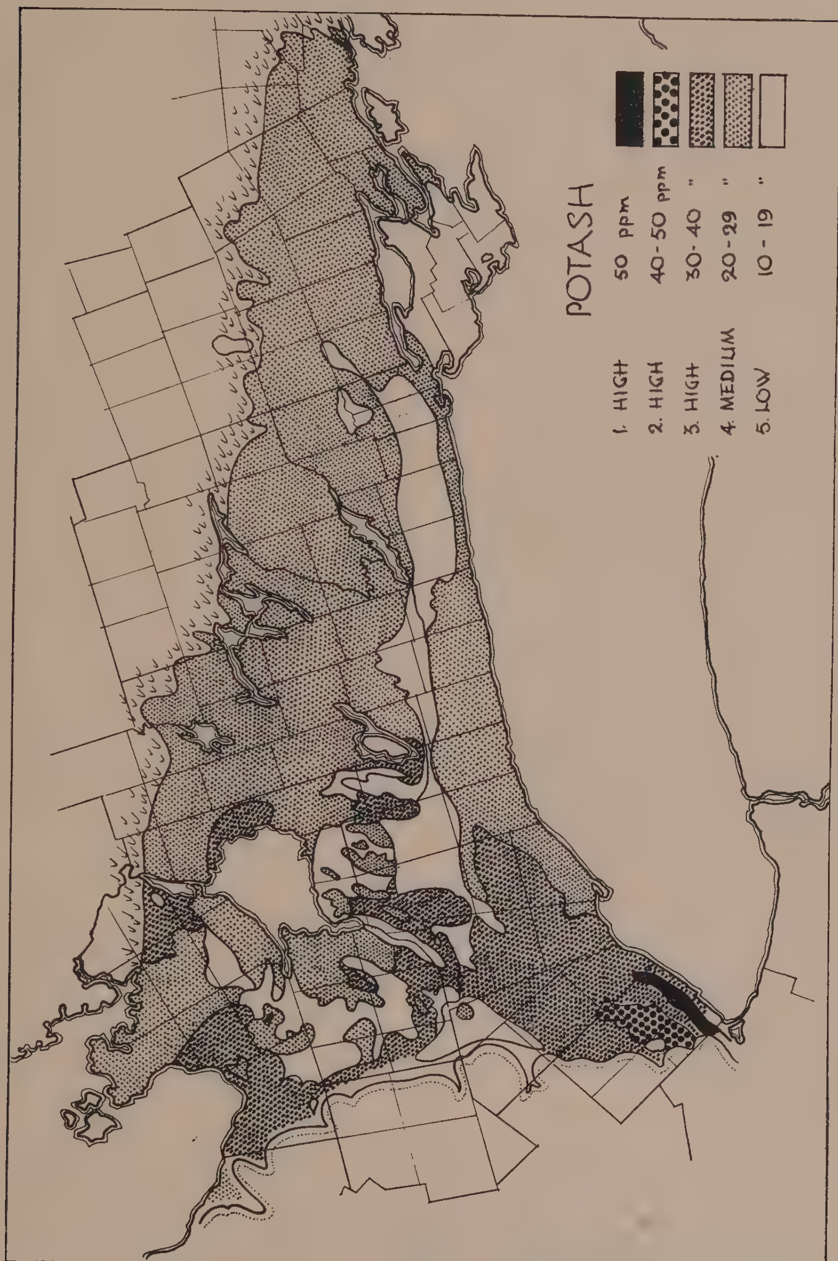

FIGURE 12. The levels of easily replaceable (avialable) potash in the soil.

extract, or from 160 to 240 pounds per acre of easily replaceable potash in the soil, are in a median group, which is still in need, but requires lesser applications of potassic fertilizer. However, when the soil contains higher levels than this, it is doubtful if potash will benefit the general run of farm crops, especially since these lands are invariably the ones which are most deficient in phosphorus.

It must be understood that, at present, the results of rapid soil tests can serve as the basis of tentative recommendations only; for while they do give an accurate measure of the relative levels of the various available nutrients in the soil, there is as yet no comparative standard of requirements for each individual crop. This handicap, of course attends practically all methds of soil analysis, and it is to be hoped that the students of plant nutrition will rapidly accumulate the necessary information.

Natural Vegetation

It has long been noted by ecologists and plant geographers that certain types of vegetation are associated with certain kinds of soil, or better, that the vegetation is more or less influenced by edaphic or soil factors. On the other hand, it is also well established that the character of the vegetation has a direct effect upon the process of weathering taking place in the soil. It is, therefore, highly important that any survey of soil characteristics also include an account of the natural vegetation.

It is not easy to reconstruct a complete picture of the original forest cover because most of the land is now cleared, and those small areas which remain have been culled to a great extent. The most difficulty is encountered on the best soils for here the area left in bush is least. From a series of notes made throughout the area, however, the map shown in Fig. 13 was constructed. In it, an attempt is made to indicate the chief associations. There are, of course, a great many more species to be found in every locality than those mentioned, the object being to list only those which predominate and therefore should be characteristic of the type of soil.

On the hilly, droughty sands of the Interlobate Area white and red pines, red oak and sumachs are common. Equally typical are the red cedar and juniper of the dry flat limestone lands, together with the mulleins and blueweed of the clearings and pastures. Where sufficient moisture is present, white cedar is also plentiful on the shallow limestone soils.

The limestone till soils support a growth of mixed hardwoods and conifers; sugar maple, ironwood, beech, basswood, white pine, hemlock and white cedar being present, but in varying proportions. Along the fences, thickets of prickly ash or toothache tree (*Xanthoxylum americanum* Mill.) are common, as is also the wild grape. The acid upland soils of North Simcoe favour beech and hemlock, but sugar maple and white pine are also common. The shaley till soils of the southwestern part of the area are typified by a tree growth consisting of white, red and scarlet oaks, hickory and sugar maple. While few pines are left today it can easily be seen from the stump fences that this was originally a white pine country not only on the loams but on the clay soils as well.

In consideration of the vegetation on the plains of the old glacial lakes, it is well to note that as a rule the soils are less well drained than those developed on till. In the Algonquin bed, the well drained sands

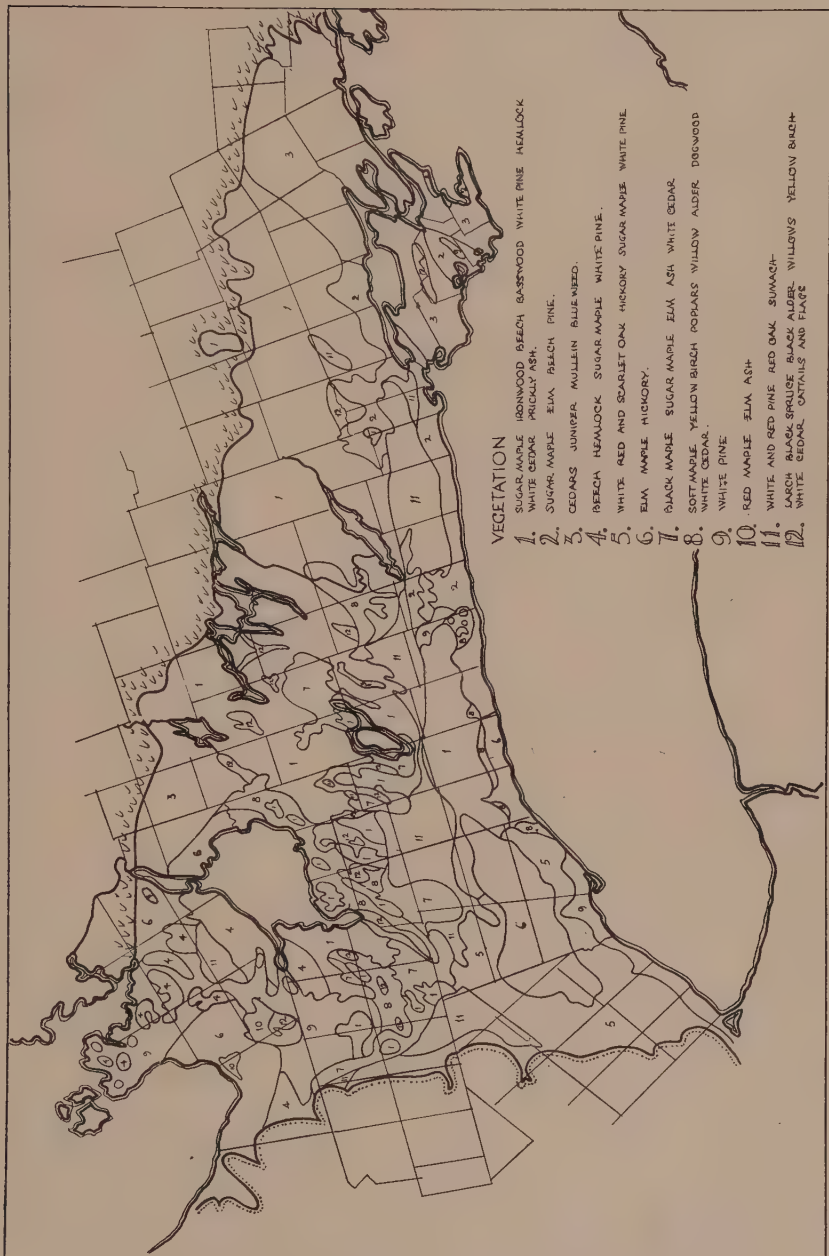

FIGURE 13. The dominant natural tree growth over the area.

and sandy loams of both the Natawasaga Valley and the Penetanguishene Peninsula were originally covered with solid white pine forests, the "Pine Plains" of other days. It is encouraging to note that some of these areas have been reforested and it is to be hoped that a great deal more will be done. Less well drained sands and loams carry soft maples, yellow birch, poplars, willows, alders, dogwood and, in the more alkaline areas, white cedars. On the poorly drained drab coloured clays which are common in the northern lowlands the chief forest trees are elms, ash and maples; the same sort of vegetation prevails on the marly soils near Minesing, red maple predominating.

In the Iroquois plain the good loam soil of Northumberland and Durham counties probably developed under a forest of sugar maple, beech, elm and pine. The lighter sands and loams carried pine forests while the clays supported elm, ash, and maple with little intermixture of soft woods. The wetter spots in the clay, as well as the undrained boulder pavements are characterized by cedar swamps. On the calcareous clay soils of the Schomberg plain, the black maple *(Acer nigrum)* is more common than elsewhere, while sugar maple, elm, ash and white cedar are also present. On the Peel plain elm, sugar maple and hickory are the prevailing trees.

Marshy soils are common in the northern part of the region, and carry several characteristic types of vegetation. Several small sphagnum bogs occur with the typical treeless association of sphagnum moss, high bush cranberry, leatherleaf and Labrador tea. Very wet locations, such as the Holland marsh in its undrained state, have sedges, cattails and flags. Many other areas with wet organic soils of varying depth are characterized by larch, black spruce, white cedar, yellow birch, black alder and willows.

Land Types

It has been previously stated that there are, relatively, a large number of soil types in the region, if the classification is done strictly on a profile basis, many of which are not encountered elsewhere in the province. By grouping those types which show similar profile development, and, to a large extent, similar topography, drainage and other physical characteristics; and by omitting some of the less extensive and less important types; it has been possible to account for most of the thirty or forty types of soil within thirteen major groups or land types. While to a large extent physical factors have been stressed, chemical characteristics are also discussed. The map in Figure 14 outlines the main areas occupied by each of the land types. It is natural of course, that this map should bear a fairly strong resemblance to that of the physiographic regions, given in a former publication (5). It will be seen, however, that physiographic regions may include several land types, and that the same land type may occur in more than one physiographic region.

In the following descriptions, the chief characteristics of each of the land types are embodied; but it will be noted that the poorer areas, such as the very wet soils, for instance, have not been studied in the same detail as have those areas of better soils which have been more extensively cleared and cultivated.

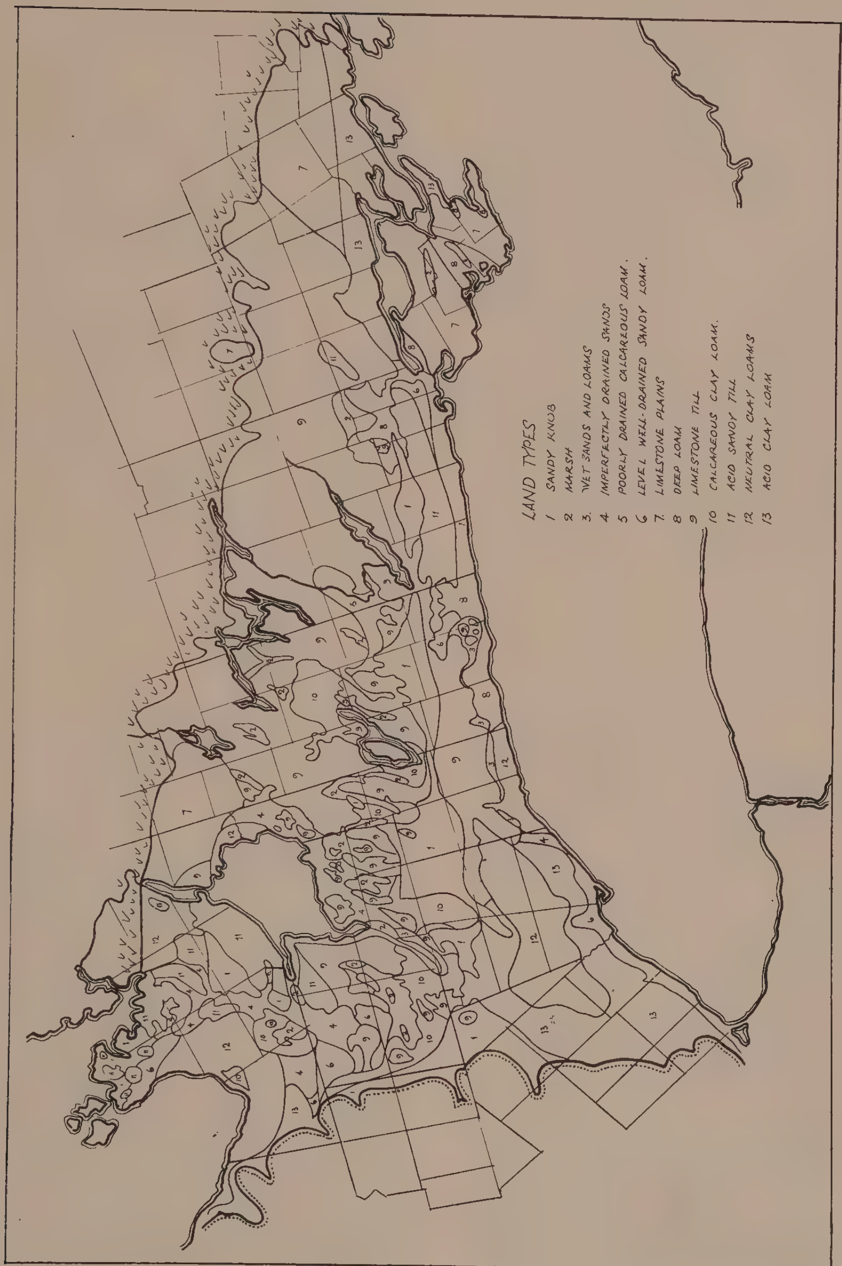

FIGURE 14. A chart of the larger areas of the different land types.

The Sandy Knob Type

This type includes the hilly, droughty, sandy soils commonly found on the sandy moraines and eskers. With these may also be classed the small areas of dune sands found on the shores of Georgian Bay and Lake Ontario. The area occupied is about 350,000 acres.

The profile development over much of the area resembles that of the Oshtemo type. There is a very shallow surface layer, a deeper, greyish-yellow "A_2" and a thin, medium-brown "B" horizon, which fluctuates greatly in depth, dips or tongues reaching down to 8 or 10 feet below the surface in extreme cases (Figure 15). It is common to find a double surface horizon caused by wind-blown sand having been deposited on the original surface which usually contains considerable charcoal. It is related that, before the advent of the white man, the Indians burned the pine forests off the ridges in order to facilitate the hunting of deer. In some of the more nearly level areas, finer sands occur, and here good soils of the Fox type are found. On the steeper hillsides there is a good deal of gullying and large blowouts are common. In many places there are knobs of boulder clay. The profile development of the dune sands is usually of the Bridgman type.

The surface horizon of the undisturbed profile is usually acid. Where a double surface layer is found it is neutral to slightly alkaline while in the blowouts and eroded spots it is, of course, calcareous.

The original vegetation was largely pine and oak forests with inclusions of maple and other hardwoods. Sumachs are common in waste areas and along the edges of clearings. In spite of its rough topography and poor sandy soils most of the interlobate area was at one time cleared and farmed, but much of it is now abandoned or used for sheep pasture only. Among the commonest grown crops are rye and sweet clover. Potatoes are locally considered to be a well adapted crop, while winter wheat is grown to a limited extent. Some years ago a number of poultry farms were established in various districts but most of them are now abandoned. In reality there are only relatively small areas that are capable of supporting farms.

Quite large acreages have been reforested. The Northumberland Forest, in the township of Haldimand was established in 1924 and enlarged to 1000 acres in 1931. Somewhat smaller reserves are located in Manvers township and elsewhere. These pine plantations present a splendid contrast to the barren wastes nearby which should also be replanted; for, without doubt, reforestation is the optimum use to which such land can be put.

The Marshy Type

Because of the irregular and scattered character of the distribution of the muck and peat deposits, they cannot be completely represented on the map. The larger areas, however, are indicated, and since most of the smaller patches occur in the same vicinities, chiefly in the more northerly sections, the regional distribution is fairly well shown. In this land type are, included all kinds of very wet organic soil, of which, as yet, very little has been improved, the largest and best known development being that of the Holland Marsh near Bradford.

FIGURE 15. The sort of soil profile commonly found within the sandy knob type.

FIGURE 16. A profile of a poorly drained calcareous fine sandy loam.

FIGURE 17. Showing the "nodular" character of the upper rock strata, a condition common in Prince Edward county.

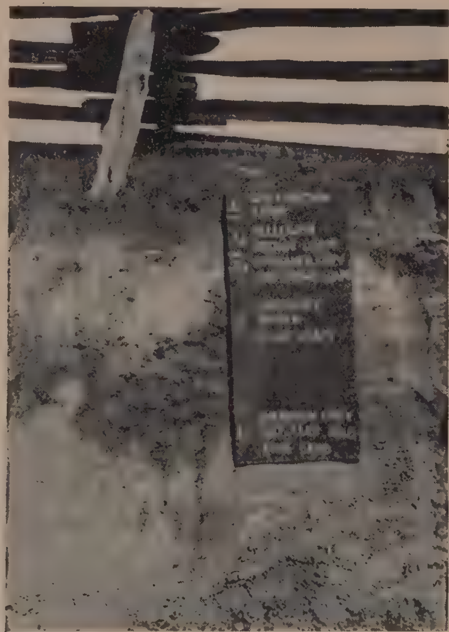

FIGURE 18. A soil profile common to the deep loam type.

The factors which govern the suitability of these soils for the growth of truck crops are too involved for discussion here but one of the chief drawbacks is the prevalence of fall frosts in these low-lying areas.

The Wet Sands and Loams Type

In this category belong all mineral soils, whether sands, loams or stony loams, which are very poorly drained. Patches of muck are inevitably associated, while the vegetation consists chiefly of white cedar, black alder, willow, elm and soft maple. Such soils are very commonly found just inside the beach lines of the extinct lakes, while those sections where there is a shallow and irregular covering of drift over the bedrock also include considerable areas. The usual profile consists of a highly organic surface horizon, underlain by grey and rusty mottled subsoils.

Very little of this type of land has been improved since it is usually stony or shallow, and at present does not justify the rather difficult task of draining and clearing.

The Imperfectly Drained Sands Type

These sands are all of lacustrine origin and usually quite level. The largest areas are found along the margins of the Algonquin lake plain in the northern part of York and Simcoe counties. The chief soil components of this land type are members of the Berrien, Rubicon, Saugatuck and Allendale series. The profile varies from that of a mature podsol with a shallow ashy grey horizon and dark brown, slightly indurated hardpan layer, to cases in which a somewhat organic surface horizon directly overlies a yellow mottled subsoil. Frequently clay or rock occurs within a few feet of the surface. They are poor sandy soils with bad internal drainage, usually acid in reaction and low in fertility elements.

Over much of the area the original tree growth was chiefly white pine, but, on some of the more poorly drained phases, yellow birch, aspen, soft maple and alders are found while brake ferns abound in the clearings.

In the north and east a large proportion of this land is unimproved, but where it occurs in the more specialized areas such as the lakeshore district between Toronto and Hamilton, such soil is usually underdrained, improved and used in the production of a wide variety of fruit and truck crops.

The Poorly Drained Calcareous Loam Type

The bulk of this land is found in the Algonquin lake plain, but smaller areas appear wherever lacustrine deposits of limestone origin are found. The topography is flat and both surface and internal drainage is poor; the texture varies from loam to fine sandy loam. The total area is about 150,000 acres, much of which is found in Tecumseh township but smaller areas occur throughout the Algonquin lake plain and also south of Peterborough and near Brighton in the Iroquois lake plain.

In most of the areas mentioned, a single characteristic type of profile development occurs. It consists of a very dark surface horizon, some six or seven inches deep, over a yellow and grey mottled subsoil of fine sand or silt. A typical example is shown in Figure 16.

It is an alkaline soil with a pH of 7.50–8.00, having free carbonates in the surface and throughout the profile. Low available potash, and low to medium phosphorus levels are typical.

Silver maple, poplars, elm, yellow birch, white cedar and alder are the most commonly associated trees, while in the clearings and fence rows, goldenrod, sensitive fern and impatience are abundant.

Much of this land is still in an unimproved state. The factor which limits its value is drainage, very little artificial drainage having been installed because of the lack of good outlets in such widespread level areas. If thoroughly drained and properly fertilized, these soils would be excellent for a wide variety of farm crops, being high in organic matter, level, stoneless and easy to till. For most crops mixed fertilizers with a fairly high proportion of potash should be used.

The Level Well Drained Sandy Loam Type

These soils are also of lacustrine origin and are found on deltas and other well drained deposits in Lakes Algonquin and Iroquois. The chief areas in which they occur are located near Alliston, Creemore, and Lafontaine in Simcoe County while smaller patches occur between Toronto and Hamilton. The total area of this land type is estimated to be 150,000 acres.

In the main, there are three distinct soil types in this group which in their profile development bear a strong resemblance to the widespread Fox series. The surface horizon is usually a brownish grey sandy loam over a deep stratified sand, fine sand or gravel subsoil. Where the subsoil is very open, there are small areas of Plainfield type, but the better soils usually contain enough material of the finer particle sizes in their subsoils to cause the development of a brown "B" layer, several inches in thickness. These soils are all acid in reaction, some more so than others. Near Alliston the surface soil usually has a reaction of pH 6.00–7.00, while near Lafontaine and in the district between Toronto and Hamilton it is slightly more acid. They are usually fairly well supplied with soluble calcium and have a medium amount of phosphorus but are low in available potash.

Solid white pine forests originally covered these areas, and in many localities stump fences are still numerous.

The agricultural development of these soils depends largely upon their location since as a rule they are fairly adaptable. In Simcoe county all the common farm crops are grown successfully except on the lightest phases, while near Alliston there is considerable specialization towards potato culture. In the district between Hamilton and Toronto these soils are in keen demand for orchards and market gardens.

The Limestone Plains Type

In the Napanee plain, and in the northern parts of Ontario and Victoria counties, there are altogether about 600,000 acres, where the soil consists of a very thin deposit over flat, stratified, limestone bedrock. In Ontario and Victoria counties the rock is almost bare over large areas, while in the Napanee area there is from six inches to a foot of either limestone till or water-laid clay. In Prince Edward County a peculiar condition exists. Some of the upper rock strata are "nodular", that is, the limestone layers readily break up into pieces not unlike coarse roadstone, while interbedded with these are thin layers of shale. The cracked limestone and weathered shale allows for somewhat deeper root penetration and creates a better soil than is usual on rock plains where the upper strata are more massive.

A typical example of type of soil, locally termed "clay gravel" is seen in Figure 17.

The associated vegetation is usually quite specific, cedars, juniper, mullein, blueweed (*Echium vulgare*) and stonecrop being common everywhere. In some places there are stands of balsam fir, while if the soil is slightly deeper than ordinary, elm and rock maple may occur.

The predominant agricultural use for this type of land is pasture, the chief forage plant being Canada blue grass, although in some places white Dutch clover is fairly abundant. In the deeper phases, where there is a foot or so of soil, hay, grain and corn are grown with fair succession some seasons. In Prince Edward County the better phase (clay gravel) is used for farm crops, corn, sweet clover and alfalfa doing very well. It is utilized for canning crops such as peas and tomatoes, and also for apples, although it cannot be considered to be well adapted to these crops.

The chief drawback to agriculture on these soils is the extreme drouthiness, and it is an odd coincidence that this shallow soil should be situated in Prince Edward County which is one of the driest climatic zones in the province.

The Deep Loam Type

The best soils of lacustrine origin comprise the deep loam type which is most abundant in the Iroquois lake plain but is also found to a smaller extent in the beds of Lake Algonquin and some of the smaller glacial lakes. There are about 100,000 acres of this land located chiefly in the vicinities of Bowmanville, Newcastle, Port Hope, Codrington, Wooler, Norham Morganston and Plainville. The surface is a smooth, even textured, fine sandy loam to silty clay loam developed on deep beds of fine sand, silt and clay. The subsoil is often considerably heavier than the surface. The internal drainage is imperfect and much of the land has to be tile drained, especially when planted to orchards.

The profile is that of a typical grey-brown earth with considerable variation arising chiefly from the textural differences in the deposits. The profile development is shown in Figure 18.

The reaction in most cases is about neutral with plenty of available calcium. There is a medium amount of available potash and medium to low levels of available phosphorus.

It is a good soil and well adapted to most crops, including cereals, clovers, grasses, corn and roots. In some districts, canning crops, such as tomatoes, corn and peas, are grown.

One of the outstanding features of this land type has been its utilization for apple growing. The counties of Durham and Northumberland have for years been justly famous for their orchards, the best of which are always found on the good deep loams. The best orchards in Prince Edward County are also found on similar soil types.

The Limestone Till Type

This is by far the most extensive land type in the region comprising between 1,500,000 and 2,000,000 acres. It is almost coextensive with the drumlin belt and in addition includes some of the Ontario till plains. Much of the land in Peterborough, Victoria, Durham and Ontario counties is of this type, but every county in the region, except Peel and Halton, includes some of it. The topography is gently rolling to hilly, with some

hillsides too steep for cultivation. In some places the land is quite stony; drainage is good except for seepage spots on some hillsides.

There are five distinct soil types, all of them loams or stony loams. Four of the types have very shallow profiles, with a coffee-brown "B" layer occurring immediately under the furrow slice in cultivated fields, the fresh, grey limey till being usually within fifteen inches of the surface as seen in Figure 19. The other type has a somewhat deeper profile since it occurs on a more sandy till.

All these soils are alkaline with pH values from 7.0 to 8.5. In the first four types, free carbonates are found intermittently over the surface in virgin areas, but are fairly generally abundant in all plowed soils; in the fifth type they are intermittently found in cultivated fields, the reaction of this soil being usually about neutral. The levels of both available potash and available phosphoric acid are usually in the medium category and complete fertilizers are therefore the logical choice for most crops.

The predominant forest vegetation consists of hardwoods, sugar maple, beech, basswood, ironwood and elm being common, while on some types there may also be considerable intermixture of softwoods such as white pine and hemlock. On the most calcareous types prickly ash is abundant in the clearings and along the fences.

Apart from those spots which are too hilly or stony for cultivation, these are good soils for general agriculture, well adapted to winter wheat, alfalfa, oats, barley, clovers, roots and fodder corn. In Victoria County sweet clover and alsike are extensively grown for seed.

The Calcareous Clay Loam Type

In the general region of the limestone till soils, there are also fairly extensive deposits of highly calcareous lacustrine clays upon which important soil types have been developed. Althogether, this land type includes about 200,000 acres, the largest tract being the area of gently rolling and moderately well-drained soils in the Schomberg lake plains of York and Simcoe counties. Included also are the marly soils of the Minesing district as well as smaller areas of clay near Uxbridge, Port Perry, Lindsay, Bethany, Baileyboro and Trenton, some of which are more poorly drained.

The level areas require artificial drains, and even the rolling soils, where drainage is generally adequate, are greatly improved by putting tiles up the main hollows and into springy spots. Considering its heavy texture, the physical condition of the soil is good, even the subsoil being relatively porous.

The reaction is quite alkaline, usually ranging about pH 8.0–8.5, while free carbonates are fairly abundant on the surface in cultivated fields. The amount of available phosphorus is almost always deficient; available potash levels are fairly high; organic matter content, medium; while available nitrogen seems relatively high to judge from the appearance of the crops. In view of this, it is probably more economical to use superphosphate alone for winter wheat and other cereals. If the soil is not in good tilth, and has not recently been manured or grown a clover crop, some nitrogen is apt to be needed, and a complete fertilizer is to be preferred.

The forest growth includes black maple, rock maple, elm, ash, basswood and ironwood on the better drained lands, while red maple appears to dominate the marly types.

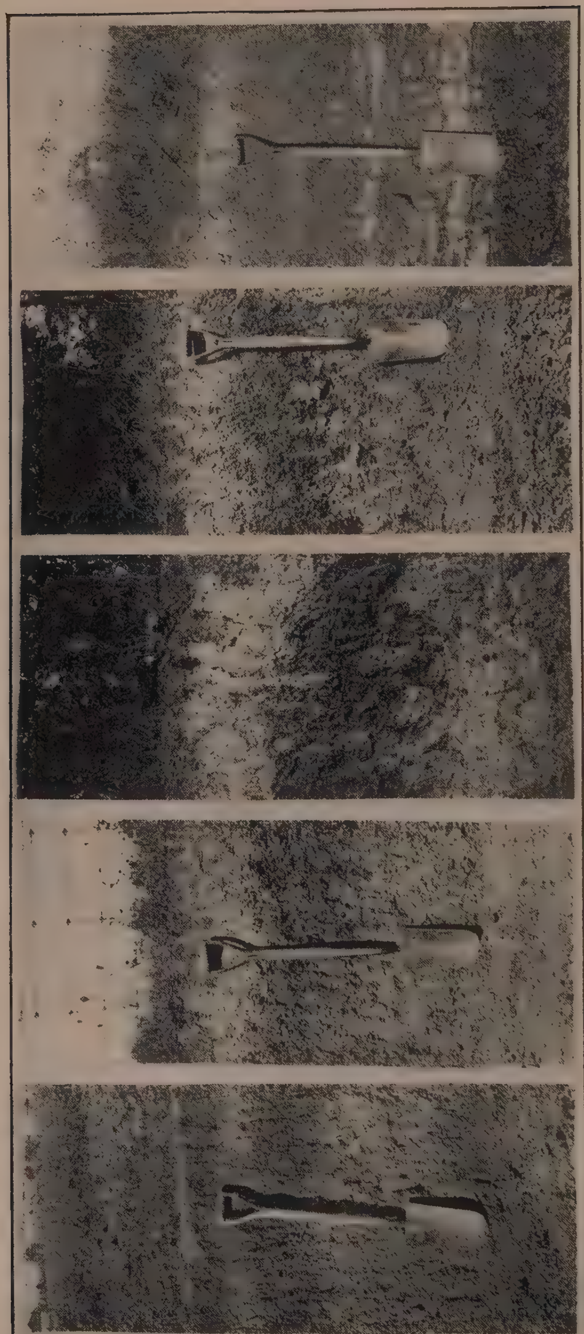

FIGURE 19. Profiles of the five limestone till soils.

This land has long been regarded as excellent for general farming and livestock raising. Winter wheat is intensively sown and produces good crops; and, except where the drainage is very poor, alfalfa and clovers do well.

The Acid Sandy Till Type

Two distinct soil types, covering about 250,000 acres, are included in this group. The first type is found on the Simcoe uplands where it is developed on a rather sandy till which is composed largely of Archaean material. The second type is found on the rather large drumlins in the southern part of Northumberland county where the usual boulder clay seems to have been buried to a depth of three or four feet by a lighter deposit. Both are well drained soils as a rule, often inclined to be stony, and in some places include slopes which are too steep for cultivation. The surface texture varies from a light loam to a sandy loam.

Both types are mildly acid and would probably benefit by the addition of ground limestone. The Simcoe County soil has better than average potash levels and a very low supply of available phosphorus, while the Northumberland County soil has about the highest phosphorus and lowest potash levels of any soil in the region.

Beech, pine and sugar maple are the predominant forest trees in both areas. Hemlock is fairly common in the northern part.

Neither of these soils can be considered as first class land but general farming can be fairly successful. A fair percentage is used for grazing. Alfalfa does not thrive in either location, its place being taken by red clover, while potatoes are a fairly well adapted crop, especially in Simcoe County.

The Neutral Clay Loam Type

All the level, or nearly level, clay loams with a reaction about the neutral point are included in this type, the total area being about 350,000 acres. The Peel Plain in Peel and York Counties comprises about half of it, the remainder being situated partly in the Iroquois Plain between Toronto and Bowmanville, and partly in the Algonquin Plain, notably near Elmvale and Beaverton.

Drainage may be quite good or poor depending upon the topography; tile drains are needed over much of the area.

The profile development resembles that of the Conover type, usually having a good horizonal development except where too poorly drained, when the subsoil is mottled grey and rusty brown. The surface soil is fairly deep and has a better than average content of organic matter. The soil in the Peel Plain has good physical condition, the crumb structure being especially noticeable in the spring. Lime is not required, and there is usually a good supply of available potash, but the level of available phosphorus is low.

The forest cover consists of rock maple, elm, ironwood, hickory, ash and basswood.

The heart of the noted alfalfa seed-producing section in Peel County is situated on this soil, but some other areas are too poorly drained to be ideal for alfalfa. Alsike clover does well and winter wheat can usually be depended upon. Spring sown grains are very largely grown; but corn and roots are not so well adapted, and potatoes do very poorly.

The Acid Clay Loam Type

There are between 500,000 and 600,000 acres of clay plains, usually with little or no relief, upon which acid soils have been developed. Some of these clays are lacustrine, but a large part of them were deposited as ground moraine. As a rule there are few stones to interfere with cultivation. The shaly soils of Halton, Peel and York counties make up the largest part of this land type, while to a much lesser extent it includes the acid clays of the Napanee plain and the old Algonquin Lake bed near Lake Simcoe.

The shaly soils include five distinct soil series: (1) the shallow red clay, (2) the flat clay loam of Halton county, (3) the red clay loam on the deeper till, (4) the rolling dull grey clay loam of Peel County, (5) the less acid till soils common to King and Scarboro townships. These soils all have a shallow surface horizon, a buff coloured "A_2" horizon of friable material and a rather compact "B" layer with a fair amount of depth, representative profile illustrations are shown in Figure 20. The first three soils are in many respects similar to soils which are fairly widely found in the Niagara Peninsula and probably constitute part of the same land type. The last mentioned soil is of distinctly better grade than the others, chiefly because of a much higher percentage of limestone material in the till and a much better natural drainage.

These soils are all acid with pH values varying from 4.5 to 6.5. They are high in available magnesium but low in soluble calcium, and with the doubtful exception of the last mentioned member, are definitely in need of lime. The shaly soils are extremely deficient in available phosphorus, but they have the highest levels of available potash to be found in the region. The amount of organic matter in the surface is low, the soils all being light in colour, fallow fields having a definite whitish cast when dry.

The natural vegetation consists of oak, pine, elm, hickory, beech, rock maple, ironwood and ash.

The profiles of the acid soils in the Napanee Plain and in the Lake Simcoe district have very drab colours and rather poor development; in the former case carbonates are not present in the subsoil which is very heavy and impervious, while the clay deposits upon which the latter soil is developed are calcareous. The surface soils are whitish when dry; poor drainage is the rule and the clay puddles and clods badly. These soils are only moderately supplied with phosphorus and potash and would benefit by the application of lime. The natural vegetation consists largely of elm, ash and maple.

With regard to agricultural adaptation there are three distinct subtypes in this land division. In the first is placed the slightly acid and better drained soils of King and Scarboro, and some of the grey shale soils. They are good general farming soils, spring grains and alfalfa do well but winter wheat is not extensively grown. Being near Toronto, dairying is the chief farm enterprise. The red shale soils are definitely inferior and need careful management. Lime and phosphate should be generously applied and the organic matter increased by the application of stable manure or the plowing under of green crops.

FIGURE 20. Profiles of the five shaly soils.

In the third sub-type, the heavy lacustrine clays, drainage is probably the first consideration. Good crops of clovers can be grown, especially when lime is applied, and in some cases alfalfa does well. Fertilizers containing both potash and phosphorus are to be recommended in most cases for general farm crops.

DISCUSSION

The physical features constitute the most implacable limits to the agricultural utilization of any land area. Foremost in importance in this respect, stand topography and its constant associate, drainage. The most prominent topographic feature in the southern part of Central Ontario is the interlobate moraine which extends in an east and west direction through the middle of the area. Much of this land is untillable because of the irregularities of the surface; while in addition there are other smaller areas such as rock cuestas, old shore cliffs, recently eroded valleys, and the steep sides of some of the larger drumlins; so that, in all, the proportion of topographically non-arable land amounts to about 8% of the total area of the region. Where the handicap of topographic relief is absent, on the other hand, the hydrographic factor is likely to be most to the fore. The area of flat, swampy and wet land, which is at present restrained from cultivation is only slightly less extensive than that of the rough hilly land.

The presence of solid rock at the surface, or with a very shallow covering of unconsolidated materials, is also a very serious handicap; nearly 12% of the area of the region must be classed as of low agricultural value on account of the lack of depth of its soils. In addition, there is possibly 5% consisting of soils so stony that cultivation is prohibited unless a disproportionate amount of labour is first expended in clearing operations.

It is thus to be seen that, because of the influence of physical factors, somewhat over 30% of the area of the region is to be classed as distinctly submarginal land. On the other hand, nearly half of the area may be rated as first class agricultural land, which, apart from climatic limitations, is as productive as any similar area in the province. The remainder is, in the main, also good land, but of a more limited productive capacity.

Notwithstanding the fact that the physical characteristics are those most definitely limiting the use of land, the chemical characteristics are important; and they are, to considerable extent, linked up with the profile development. The region lies in the zone of the podsolic soils, with mature podsols occurring in some of the more northerly areas, and it is therefore to be expected that leaching is fairly active, and that only moderate amounts of available nutrients will be present. Pedologically speaking, however, they are mostly young soils; hence, they are still greatly influenced by the original constituents of the parent materials.

The outstanding characteristic of the region, from a chemical standpoint, is the relatively large area of alkaline soils, much of which has also free carbonates in the surface layer, especially in cultivated fields. Associated with this is the fact that, even in soils which are somewhat acid, there is plenty of available calcium. In fact, the application of lime in any form is not required for approximately 80% of the area. Magnesium is also usually sufficient. On the other hand, in no case is there more than a moderate amount of available phosphorus, while there

is much land in which there is an acute deficiency. The supplies of available potash are much more variable and range from a condition of acute deficiency to those cases where no addition is necessary. It is, therefore, evident that all fertilizer recommendations should be based upon the natural levels of fertility in the soil as well as the normal requirements of crop plants.

The land type, as here presented, is an attempt to sum up the edaphic factors in such a way as to facilitate the study of land utilization. It is possible that further study, and, especially, comparison with conditions in other parts of the province, will necessitate changes in some of the boundaries. In general, however, the chief types outlined in this scheme will remain a basis for ecological and economic investigations and will point hopefully to the day when similar knowledge will have been made available for the whole province.

CONCLUSION

The southern part of Central Ontario has an interesting and, in some respects, unusual set of soils. Because of the complex geological history of the parent materials, the types are many and varied; hence a complete classification of all the members and an accurate mapping of the same will come only with a detailed soil survey. In the meantime, it is useful to have a general description embodying those physical factors, such as topography, drainage, depth and stoniness, which limit the use of land, as well as those factors of natural fertility which govern soil treatments. Finally by taking into consideration the morphological features of the soil profiles, and by grouping those types which show similarity in the chief characteristics, it is possible to classify thirteen land types which constitute fairly well defined units in the study of agriculatural adaptation. It is, therefore, to be hoped that this account of the soils of south-central Ontario will serve the purposes of geographers and ecologists, and until more detailed soil surveys are made, will constitute a guide to soil treatments, as well as a basis upon which to plan actual tests with fertilizers and different varieties of crop plants.

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METHODS AND RATIONS FOR FATTENING POULTRY[1]

II. EXPERIMENTAL TECHNIQUE AND COMPARATIVE VALUE OF FATTENING RATIONS

H. S. Gutteridge[2]

Central Experimental Farm, Ottawa

[Received for publication November 12, 1937]

TECHNIQUE

The technique employed in the carrying out of the fattening tests here reported was similar to that previously used and which was set forth in detail in the previous publication of this series (2). Such changes as were made will be noted briefly.

Allotment

The allotment of the cockerels to individual cages of the fattening battery was completely at random in this instance. As an outcome of previous fattening tests it was determined that not less than 40 birds were necessary in each experimental group if small differences (6 to 10%) between treatments were to be demonstrated to be of significance. In employing this relatively large number of birds it was found that the different groups started the test at closely comparable body weights when random allotment was used. This finding was further strengthened by the fact that statistical adjustment of gain for differences in initial weight was negligible when as many as 40 birds were used for each group.

As in previous tests allotment of diets to the individual birds was also at random.

Feeding and Management

Feeding and management was identical to that previously reported. Any differences occurring because of the experimental treatment imposed will be set forth under the experimental detail of each test later in this publication. The tests were of three weeks duration.

Sampling

In the first paper of this series (2) the dressed carcasses of the experimental birds were sampled for determination of fat in such a way that the distribution of fat in the different areas of the carcass could be determined. Since the data obtained clearly indicated that the experimental treatments imposed had no effect upon the deposition of fat in different areas, it was considered to be unnecessary to use distribution of fat as a criterion of the fattening efficiency of a feed or treatment in these tests. As a result the sampling carried out was upon a somewhat different basis.

It was previously shown that degree of fatness at the end of a fattening period was a relatively poor indication of the actual increase in fat during fattening. Preliminary trials were therefore commenced in order to find if possible some measure of the actual increase in fat during the fattening period.

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[1] Contribution from the Division of Poultry Husbandry, Dominion Experimental Farms, Department of Agriculture, Ottawa.

[2] Poultry Husbandman.

The findings of Hankins and Ellis (3) that thickness of back fat in hogs was a reliable index of the percentage of fat in the carcass was found not to be of practical application to poultry, largely because of the extreme thinness of the fat in that area and of the consequent difficulty in accurate measurement. The percentage of fat in numerous samples of back fat was determined but was found to be a poor indication of the fatness of the carcass as determined by the percentage of abdominal and skin and subcutaneous fats. Difficulty in sampling appeared to be largely responsible for this finding since the great variation in thickness of fat in different areas of the back of poultry precluded the possibility of obtaining an accurately representative fat sample.

A considerable amount of difficulty in finding an area where fat was deposited subcutaneously in sufficiently large and uniform quantities for this purpose was experienced. It was finally found however, that the large feather tract upon the breast parallel to the keel suited the purpose admirably. In three different groups of dressed poultry the percentage of fat in the feather tract sample was found to be highly correlated with the percentage fat of the carcass the actual correlation values ranging from $r = +0.87$ to $r = +0.98$. The following technique was finally adopted.

Prior to commencement of the 24-hour period of starvation which precedes each test each bird was sampled individually. An attendant quickly removed the feathers from the anterior end of the feather tract and injected 5 minims of adrenalin chloride solution (1-1000) into the skin at the base of the feather tract and near the site of operation to prevent excessive bleeding. A local anaesthetic was then applied in the form of ethyl chloride. When freezing had progressed sufficiently the operation was performed. A strip of skin with adhering subcutaneous fat approximately one-half centimetre wide, at right angles to the feather tract and exactly the width thereof, was removed and transferred to a weighed test tube. Since the subcutaneous fat of the feather tract diminishes in thickness from the centre of the tract to the outside edge both ventrally and dorsally and also diminishes in both width and thickness anteriorly it was found to be essential to sample at the same relative distance from the anterior point of the feather tract in each bird in order that the samples taken might be strictly comparable. After removal of the sample the bird was released without suture of the wound. It should be stressed that since skin and subcutaneous fat only are required there exists no necessity for injury to the breast muscle tissue in any way. In only a very few instances did persistent bleeding occur and infections were but rarely encountered and those not severe in nature. Further, no evidence could be found to indicate that the birds had received a set-back through this operation, appetite and fattening apparently being normal throughout.

At the completion of the fattening test the birds were slaughtered and an identical sample from the feather tract of the opposite side of the body was taken to represent the degree of fatness at the end of the fattening test. That the two sides of the same bird are in excellent agreement as to level of fat in skin and subcutaneous tissues was previously reported by the author (2). The difference in percentage fat between the sample taken before and that taken after fattening represents the increase of fat in that area during the fattening period, and in view of the excellent correlations between the

fat content of such samples and that of the whole bird, this difference was considered to be an excellent indication of the increase in fatness brought about by the fattening treatment for the individual concerned. Percentage increase in fat in these papers refers therefore to the increase thus obtained.

Chemical Analyses

The samples of the feather tract taken as above were placed in weighed test tubes and the weight of tube and sample recorded. Concentrated HCl was then added to each just sufficient to cover the sample. After digestion in a water bath until completion the fat was determined by the Mojonnier method. The fat obtained was then expressed as percentage of the original weight of the sample.

Increase in Fat

As was found to be the case with gain, increase in fat varied considerably from bird to bird. Analyses of the data obtained indicated that percentage gain in weight and percentage increase in fat during fattening were related only to a small degree showing an actual correlation of $r = +0.25 \pm 0.076$. It must be presumed, therefore, that a large portion of the actual gain must be in the form of protein (as muscle tissue), water, or minerals (largely bone materials). It is quite apparent therefore that increase in weight during fattening is an indifferent indication of the increase in fatness of the bird. In order therefore, to determine the efficiency of any feed in promoting the fattening or finishing process, as it is sometimes called, both the gain in body weight and the increase in fat must be determined. On correlating the percentage initial fat with the percentage gain in fat it was found that a fairly high negative correlation existed, *viz.* $r = -0.67 \pm 0.044$. As would be expected therefore, the less fat which a bird possesses at the commencement of a fattening period the greater the increase in fat will be, on the average, during that period.

A brief discussion of the practical aspects of increase in fat as opposed to gain in weight may be in order. Fattening for market is generally considered to be necessary for two reasons, namely, to increase the amount of fat upon the bird thus greatly improving its edible qualities and its saleable appearance, and to increase the weight of the bird at the same time. Increasing the fat, besides making the bird more attractive for sale purposes, places the bird in a higher market grade, thus demanding a premium of usually a minimum of two cents per pound for each grade of improvement. Under the present system of Dominion Government grading, therefore, the actual increase in fat brought about by the fattening process returns a special premium to the producer over and above the profit obtainable by reason of the actual increase in weight during fattening. It is important to note that the premium per pound is obtained not only upon the increased weight caused by the fattening treatment but upon each pound of the birds' weight; *i.e.*, if a 6-pound bird, in fattening, improved by one grade and was raised to 7 pounds in weight, besides the profit from the added pound of weight a premium of at least 14 cts. is obtainable as a reward for the increase in quality.

In determining the value of any feed or treatment for fattening purposes, therefore, the necessity for knowing the ability of that feed or treatment to increase fat as well as body weight becomes obvious. As a consequence, increase in fat represents an indispensable criterion of efficiency in experimental fattening tests.

COMPARATIVE VALUE OF FATTENING RATIONS

One series of fattening tests has been carried out to date based upon the experimental technique just considered. The test comprised 4 groups of 40 Barred Rock cockerels each on a different feeding treatment as indicated below. The cockerels were fattened in an individual compartment battery so that individual feed consumption figures would be available. Two feeds daily were given, morning and evening each of 20 minutes duration. The feeds given to each group were as follows:—

Group A—Ground yellow corn plus 5% of feed molasses mixed with skim-milk.

Group B—Ground yellow corn plus 5% of ground oyster shell mixed with skim-milk.

Group C—Ground yellow corn plus 5% of mutton fat mixed with skim-milk.

Group D—Control group—ground yellow corn mixed with skim-milk.

The feeds being contrasted for fattening efficiency have been investigated at various times by different workers. Some disagreement exists as to the efficiency of the feeds used, and the experimental techniques in some instances, particularly in the older experiments, were open to question. Bittenbender and Lippincott (1) reported as a result of their experiments that the addition of 10% of molasses to a fattening ration slightly increased the average gains on a somewhat smaller feed consumption. It did not, however, appear to improve the palatability of the ration. Since molasses represents a product composed largely of sugars, the work of Hartwell and Kirkpatrick (4) is of interest. They found that sugar at the rate of 20 to 100 grams per quart of milk used in mixing the fattening ration did not increase gains or palatability.

Calcium salts of organic acids were found by Solun and Schuster (7) to influence favourably the appetite of animals during the whole fattening period and because of resultant increased feed consumption, the quantity and quality of gain. They concluded that acid base balance is one of the main factors in regulating the appetite of the fowl during fattening.

Lee (5) after summarizing the fattening processes of a large number of fattening establishments came to the conclusions that the addition of 6% of tallow gave less uniform results than the ordinary ration and required the same amount of feed to produce one pound of gain. In Wright's Book of Poultry (8) the practice of adding fat to the ration is set forth in great detail and its efficiency unquestioned. Recently the Ministry of Agriculture and Fisheries of Great Britain (6) have published data in which the addition of 6 or 7% of mutton tallow increased gains in 18 out of 20 groups of birds. These results were obtained by cramming rather than free feeding and for a period of 10 days subsequent to a similar period of trough fattening.

It should be mentioned that ground yellow corn was used as the control ration because of its marked superiority to other grain rations used in previous tests (2).

Reviewing the experimental feeds set forth above, molasses was used as a presumably readily available source of carbohydrates (sugars in this instance) which might well supplement the carbohydrates and fat of the

grain ration with resulting increase in fat. Calcium carbonate was used as a supplement since it was felt that some form of calcium might well increase the consumption of feed and hence improve fattening. Ground oyster shell was the calcium supplement used since it is a cheap and easily obtainable form of calcium carbonate. Fat, and particularly mutton tallow, has been used for many years for fattening purposes and has been considered to be very valuable for fattening. It is claimed particularly to lay down a quality of fat which greatly enhances the appearance of the dressed bird. Mutton tallow was therefore used in order to justify these claims or otherwise in a controlled experiment under fattening conditions similar to those in commercial practice, and fed in a more practical manner than the usual cramming method. The supplements mentioned were all, with the exception of molasses, added to the dry ground corn (the tallow in rendered form) and the skim-milk added so that the same amount of milk was used in each ration. In order that the consistency of the mixed mash might be similar for all pens a small amount of water was added to the skim-milk where necessary to bring each to the proper consistency. It was found to be more advantageous to add the correct amount of molasses to the skim-milk thoroughly mixing it in before adding the ground corn. The mutton tallow when melted was quickly mixed before cooling with a small amount of corn meal and this in turn mixed with a larger quantity to assure thorough mixing. Where lumping of the fat occurred the mixed corn and fat was forced through a screen so that a thorough mixing of the fat was possible.

Results

TABLE 1.

Group	No. of birds	Actual gain	Adjusted gain	Consumption dry matter	Increase in fat	Adjusted increase in fat
		gms.	gms.	gms.	%	%
A. Molasses	37	439.1±28.2	395.3±13.4	2705±62.0	17.4±1.24	17.3±0.85
B. Calcium carbonate	40	472.3±27.1	410.3±12.9	2839±59.5	18.3±1.18	18.0±0.80
C. Fat	39	516.7±27.4	567.7±13.1	2662±60.2	20.0±1.18	21.4±0.83
D. Control	39	425.0±29.4	416.5±13.1	2581±60.2	15.4±1.19	18.1±0.82

Table 1 indicates the results obtained. It will be noted that the data from five individuals were not used in calculating the results. Of these, one individual died during the test, one injured its beak so that it was unable to feed, one individual was definitely sick and consumed no feed, while two others consumed so little feed that their maintenance requirements could not be met so that fattening was out of the question. Individuals whose gain is apparently abnormal, either on the high or low side, and which might logically be eliminated on a statistical basis were not eliminated in these tests unless their feed consumption was so low as to be submaintenance and there was therefore no possibility of their gain or loss being a reflection of the value of the feed which they received for fattening purposes.

As previously reported in this series, actual gain was adjusted for the effect of varying feed consumption so as to place the gain upon the basis of expectancy with equal feed consumption. In these tests the

percentage increase in fat was adjusted for the effect of initial percentage fat on increase in fat. Not only does the application of this statistical treatment increase the value of the comparison because of holding the variables feed consumption and initial weight constant, but the standard deviations of gain and of increase in fat were reduced from 169 to 81 and from 6.76 to 4.97 respectively. Actually therefore the sensitivity of the test was increased by approximately 47% by the adjustment of gains for effect of feed consumption on gains and that of increase in fat for effect of initial fat by 27%.

Gain in Weight

Considering the results obtained in assaying the value of the feeding treatments given, it will be noted that group C receiving mutton fat was significantly greater in actual gain than all other groups with the exception of that receiving calcium carbonate. When the gain is adjusted for the effect of varying levels of feed consumption the gain of the group receiving fat is again outstanding being significantly greater than that of all other groups. This efficiency of use of feed is reflected by the fact that the percentage of fat in the faeces of the fat-fed pen was not significantly greater than that of the control. All other differences are too small to be of significance. From the standpoint of gain in weight, therefore, the addition of 5% of mutton tallow to a fattening mixture of ground corn and skim-milk is outstanding, the actual increased gain on an equal consumption basis through this addition being 27%.

Feed Consumption

In the matter of feed consumption, as indicated by the data, the group receiving calcium carbonate was outstanding with a 10% and significantly greater feed consumption than the control group. Since no other group had a significantly higher feed consumption than the control group the supplement calcium carbonate obviously caused a very definite increase in feed consumption.

Increase in Fat

Considering increase in fat which, as noted, is the best criterion of the ability of a feed to fatten, it is apparent that the addition of mutton fat to the ration has given outstanding results. In actual increase, there is a difference of a 23% greater increase in fat where 5% of mutton fat was fed. When the actual increase is adjusted for the effect of varying degrees of fatness at the commencement of the fattening period thus furnishing a fairer basis for comparison, the group receiving fat is still outstanding (15% difference), the other three groups being approximately equal. It may be concluded therefore that the addition of 5% of mutton fat to the cereal fattening ration used definitely increased the level of the fat deposited in the body. The use of molasses apparently did not affect either gains or increase in fat.

Quality of the Dressed Bird

In order to measure the actual visual quality of the birds which received the various feeds all birds were graded according to the Official Canadian Government Standards for Dressed Poultry by an officer of the Poultry Services of the Live Stock Branch. Such grading is based largely upon

two qualities, namely, the degree of fatness of the bird and the body conformation. Since in groups of similarly selected and treated stock whose numbers are as large as those herein (40 birds per group) each lot should be reasonably similar at the start of the test, grade differences of any magnitude may without doubt be safely attributed to the experimental treatment given. As definite evidence in support of this contention the fact may be cited that no differences could be demonstrated in the breast angle, the most important measure of conformation, between groups. The actual grading of the birds was as follows:—

Grade	Molasses %	Calcium carbonate %	Mutton fat %	Corn %
A	47.3	55.0	74.3	57.5
B	52.7	45.0	25.7	42.5

It is quite apparent from the above data that the greater increase in fat of the group receiving mutton fat is reflected in the actual grade which the birds attained, a difference of 16.8% more grade A birds being indicated. It would also appear that the difference in the percentage of grade A birds between the control (corn) and molasses pens (10.2%) may be of some significance. In spite of the fact that these groups were of equal fatness at the end of the test (55.52% and 56.65% respectively) the molasses fed birds were degraded presumably because of a less attractive finished appearance.

SUMMARY

Technique

The matter of the most desirable technique in fattening experiments has been further investigated. The data reported herein have added to the available information to some degree. A contention previously made has been further strengthened in that under favourable conditions of fattening environment and using statistical technique which reduces variability to a very great degree, at least 40 individual birds are required in each group in order to be able to demonstrate small differences of practical value (6 to 10%) in the effect of feeds or treatments to be significant. Further, with the variability experienced in fattening tests at this institution during the past three years, unless adjustment is made statistically for the effect of variation in feed consumption on weight gains, differences of less than 10 to 15% cannot be demonstrated.

Since it was considered to be necessary to determine the ability of a feed to increase the amount of fat deposited during fattening as well as its ability to influence the degree of gain in weight, the possibility of sampling live birds at the commencement of a fattening test and their dressed carcass at the end in order to determine the increase in fat was investigated, a satisfactory technique, the details of which have been set forth herein, resulting. By the application of this technique it was found to be possible to estimate the increase in fat with a reasonable degree of accuracy.

Comparative Value of Fattening Rations

The above techniques were applied in fattening tests to determine the value of the following rations: A—ground yellow corn + 5% molasses; B—ground yellow corn + 5% of calcium carbonate; C—ground yellow

corn + 5% mutton fat; D—ground yellow corn (control). All rations were mixed with skim-milk.

It was found that the addition of 5% of mutton fat increased the gains made by 18%. On the basis of equal feed consumption it increased the gains by 27% indicating that the efficiency of the feed as a producer of gain was considerably greater when fat was added. In addition the actual amount of fat deposited upon the body during the experiment was increased by 23% by this supplement. It happened, however, that the birds of this group were, by chance, less fat than those of the control group at the commencement of the test. Since leaner birds put on fat in greater quantities regardless of the ration fed, when allowance was made statistically for this unfair chance advantage, the actual greater increase in fat for the fat fed pen was reduced to 15%, still a substantial increase in fat producing ability. Finally, the increase in fat thus made was largely responsible for superior grading of the birds according to Canadian Government Standards, there being 17% more A grade birds in the group fed mutton fat.

The addition of 5% of calcium carbonate to the ration increased the gain made by 10%, a non-significant increase. As this increase was made upon a much greater feed consumption, the efficiency of production of gain was therefore not increased. Feed consumption, however, was significantly increased by 10%. Since the body weight of all groups was almost identical at the commencement of the test no greater requirement for maintenance existed for this group and consequently it may be safely considered that this addition definitely increased the palatability of the ration.

The use of 5% molasses in the fattening ration had no significant effect upon gains, feed consumption or increase in fat, detrimental or otherwise, although the actual grading of the dressed birds of this group was definitely inferior to that of the control group.

CONCLUSIONS

Technique

1. The most valuable criteria of the quality of a feed or treatment to fatten poultry, namely, gain in body weight and increase in fat, have consistently been found to be so variable that the following measures of technique are considered to be necessary:—

(a) The use of a relatively large number of individuals in each experimental group (at least 40 under the conditions of these tests).

(b) The reduction of variability and the adjustment of means for the effect of correlated variables such as feed consumption, initial body weight, initial level of fat, etc. which if not adjusted for, seriously affect the validity of the comparisons made.

2. An efficient technique for estimation of the increase in body fat during fattening tests has been determined and may be used to very satisfactorily assay this criterion of fattening ability.

Fattening Trials

1. The addition of 5% mutton fat to a fattening ration increased the gain by 18%, the efficiency of use of feed by 27%, the increase in percentage of fat by 15%, and the percentage of A grade birds by 17%.

2. The addition of 5% calcium carbonate (ground oyster shell) to a fattening ration improved palatability as indicated by an increase in feed consumption of 10%.

3. The addition of 5% of molasses to a fattening ration did not affect gain in weight, feed consumption or increase in fat. Fewer A grade birds by 10% were produced by this addition, however.

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THE HIGH COMPRESSION ENGINE FOR THE FARM TRACTOR[2]

E. A. Hardy[1]

University of Saskatchewan, Saskatoon, Sask.

In 1931, when attending the A.S.A.E. Convention in Iowa, the author met Mr. G. Grieger of the Ethyl Gasoline Corporation, who outlined the work then being done experimentally with the high compression engine for the farm tractor. At that time the high compression engine was being placed in the automobile with remarkable results as to economy and increased horse power. The research work on antiknock fuels was well in hand, and distribution of the fuel throughout North America was sufficiently complete so that it could be had practically in any locality.

The position of the farmer in 1931 and since that time has not been good. He has been trying to use cheaper fuels in an attempt to reduce cost per acre for the power used in producing crops. Consequently, the tractor manufacturer was not ready to change from a general type of all-fuel engine to a special-fuel engine for tractors. Since 1931, however, the automobile manufacturer has gradually increased the compression ratio in the automobile engine. Table 1 shows the increase in compression ratio and H.P. per cubic inch of displacement:

Table 1

—	Ave. comp. ratio	H. P. per cu. in. displacement
1931	5.23	0.344
1932	5.29	.353
1933	5.57	.376
1934	5.72	.388
1935	5.98	.398
1936	6.30	.410
1937	6.50	.420

The power of the automobile engine was increased 92% from 1925 to 1936 while the size of the engine was increased only 11%. The power increase has been due to higher speed and increase in compression.

The designer of the tractor has been watching the results of the development in the automobile and truck engine with considerable interest. He has seen the motoring public accept the high compression engine and the special fuel which must be used for performance, without criticism. The power and economy of the high compression engine in the automobile and truck were both important factors in producing the engine performance which was demanded by the motorist.

Economy is the main demand of the farmer, generally speaking. He does not need the extra power. Consequently, the tractor designer has hesitated somewhat in changing over to the high compression tractor engine until the demand from the farmer is more urgent.

There is no question as to the fact that the present tractor engine which uses gasoline, kerosene or distillate equally well cannot be most efficient on any one fuel but the lowest grade. Table 2 shows the efficiency and power of engines tested on various fuels.

[1] Professor of Agricultural Engineering.

[2] Paper read before the Agricultural Engineering Group of the C.S.T.A., at the University of Saskatchewan, June 1937.

TABLE 2

Test No.	Fuel	H.P.	Economy H.P.Hr.	Temperature, ° F. Rad.	Intake	Exhaust	Remarks
Hart-Parr 18-28							
1	Plain	24.9	0.75	159	149	953	No ping
2	Green	24.8	0.75	158	140	950	No ping
3	Red	24.7	0.75	161	144	948	No ping
4	Plain tractor gas	21.5	0.74	144	140	980	No ping
5	Plain tractor gas	21.7	0.71	171	200	1020	Hot manifold
6	Kerosene	24.9	0.763	176	215	1000	No ping
7	No. 1 distillate	26.0	0.771	198	220	1020	No ping
8	No. 2 distillate	25.16	0.78	191	210	1025	No ping
9	No. 3 distillate	25.9	0.78	194	215	1030	No ping
McCormick-Deering 22-36 Standard Pistons							
10	Plain	31.9	0.73	170	156	1210	No ping
11	Green	32.6	0.74	174	142	1180	No ping
12	Red	31.3	0.74	173	150	1175	No ping
McCormick-Deering 22-36 8000 Altitude Pistons							
13	Plain	—	—	—	—	—	Violent pinging
14	Green	32.4	0.62	162	133	1005	
15	Green	39.7	—	—	115	—	Pinging starts
16	Green	41.1	—	—	115	—	Max.
17	Red	38.1	0.576	177	135	1040	No ping
18	Red	42.1	—	—	110	—	Ping starts
19	Red	44.0	—	—	110	—	Max.
Hart-Parr "70" High Compression							
20	Green	17.9	0.66	—	—	—	No ping

The engine of the farm tractor designed to burn kerosene or distillate does not burn gasoline more efficiently. It will usually develop more power from gasoline. The tractors which we have tested have shown greater maximum power from gasoline than from the heavier fuels: *e.g.*, Case L, 43.5 H.P. as compared to 38.2 on distillate; Hart-Parr 27.8 as compared to 26.8 on distillate. The tractor designed to burn distillate which is operated by a man who knows how to condition the tractor for distillate burning, operates for less per acre than the same tractor using gasoline, the reason being that the field efficiency is practically the same and the weight per gallon of fuel is less as well as the cost being less (gasoline 7.4 lbs. kerosene 8.02 lbs. and distillate 8.2 lbs. per gallon).

The question of wear when using distillate is dependent on the individual engine and the routine care given by the operator. There are many 10- and 12-year old tractors which have operated on all fuels very satisfactorily as far as wear and upkeep are concerned, while there are others which seem to have worn out for some unknown reason. The fuel has usually, in such cases, borne the blame. Our experience would tend to indicate that when the engine is operated intelligently and is kept in good condition no extra wear can be charged to the fuel used.

The cost of lubricating oil is usually higher. The common practice of changing the oil every 60 hours as compared to 100-120 hours and dis-

carding the oil brings about an increase in cost. The quality of the oil used and the cost of the oil is the same for both fuels.

We have found that there are many farmers who have never used either kerosene or distillate satisfactorily. These men have consistently used gasoline, and many have used green gasoline thinking that the green gasoline would give better results than the plain. This percentage would be 30% in some areas and as high as 50% or 60% in others where crops have been more consistent. For such operators the high compression engine on the tractor certainly will make a saving. The Nebraska test on the Twin City M.T.A. and K.T.A. is a good example. Using the same engine and tractor except for the compression, the tractor developed a H.P.Hr. on 0.697 lbs. of fuel on distillate and 0.545 lbs. on gasoline with the high compression. The saving was 21.8%. It also operated on $\frac{3}{4}$ load on 0.740 lbs. per H.P.Hr. as compared to 0.595 lbs. per H.P.Hr. on gasoline with a saving of 19.6%. The saving on the drawbar is practically the same, 0.988 lbs. on distillate and 0.795 lbs. on gasoline, being a saving of 19.3%.

The cost of gasoline varies throughout the province of Saskatchewan according to the freight charges. The Saskatoon prices to the farmer delivered in barrel lots are as follows:

Red Ethyl	27.3¢ per gallon
Green Ethyl	25.3¢ per gallon
Plain first grade	25.3¢ per gallon
Plain third grade	20.8¢ per gallon
Distillate	19.3¢ per gallon
Diesel Fuel	16.6¢ per gallon

Basing the fuel price study on the price of distillate the cost of plain third grade gasoline is 7.75% higher, and first grade or green gasolines are 31% higher, which means that the operator who was successfully using distillate loses the saving made by the increase in engine efficiency made by the increase in cost of the fuel. However, the man using green or first grade plain gasoline in an engine with standard compression can make the full saving of 19.3% in the case of the Twin City by using the high compression engine. The spread in price between the tractor gasoline and third grade gasoline is high enough to just about equal the increase in efficiency of 21.5%.

There are a number of tractors shown in the Nebraska test lists which are high compression. Hart-Parr "70", Test No. 256 showing 0.564 lbs. of fuel on the belt and 0.809 lbs. on the drawbar. The Co-Op No. 3 tractor, test No. 274, with 0.561 lbs. on the belt and with 0.649 lbs. on the drawbar. The drawbar tests, however, are made on rubber also Co-Op No. 2, 0.580 lbs. on the best and 0.654 on the drawbar with rubber.

There are a number of tractors with standard equipment which may be changed over to high compression if desired by putting in high altitude pistons and liners. The 8000 altitude pistons were tested out in comparison with standard equipment with quite satisfactory results as indicated in Tests 10 to 19 inclusive. The high compression engine on the farm tractor makes a direct fuel saving for the tractor operator who is at present using gasoline which is ample to warrant the change to high altitude piston equipment or to the high compression tractor.

AN ANNUAL SWEET CLOVER (*M. ALBA*) OF THE DWARF BRANCHING TYPE[1]

T. M. Stevenson[2] and W. J. White[3]

Dominion Forage Crops Laboratory, Saskatoon, Sask.

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A sweet clover plant, which blossomed profusely and matured an abundance of seed during the first year's growth, appeared in a single plant progeny of Alpha 3, a dwarf branching biennial form of *M. alba*, in the field nursery at Saskatoon in 1932. All of the remaining plants in this progeny were of the dwarf branching type and none of them produced any flowers during the same year that they were sown. Not infrequently biennial plants of common white blossom sweet clover produce some flowers during the year of seeding, but blossoming on such plants usually begins late in the season and only a few seeds are matured; hence, since this plant produced an abundance of mature seed, the same year that it was sown, it appeared to be annual in habit of growth. A close examination of the plant showed that no crown or resting buds were formed such as are normally produced by the biennial sweet clovers and the plant failed to make any growth the following spring.

All of the seeds produced on this annual plant in the field resulted from open pollination. A number of cuttings were made from the plant, however, and these were rooted and grown to maturity in the greenhouse during the winter of 1932–33. Self-fertilized seeds obtained from the cuttings were sown in 1933 and approximately 100 plants were grown in the field nursery. All of these plants behaved as true annuals, blossoming and maturing an abundance of seed during the year of seeding. All of the plants were also of the dwarf branching type.

An isolated increase plot was sown in the spring of 1934 and the plants produced seed under field conditions. Since that time a number of seedings have been made, both for seed increase and for bee pasture purposes.

Comparison with the Common Biennial White Blossom Type

Botanically, this plant differs from the common biennial white blossom type of *M. alba* in several characteristics. It is distinctly annual in habit of growth and makes rapid growth early in the season. It begins to flower almost as early as many of the biennial varieties and earlier than some of them. It matures an abundance of seed, does not produce crown or resting buds, and dies during the season of seeding. The roots are somewhat smaller and less fleshy than those of the biennial forms. Flowering begins from the first to the tenth of July, at Saskatoon, while the plants are from 6 to 8 inches tall. Flowers are produced in increasing abundance as growth continues, usually reaching a maximum in late August and then decreasing until late September when the plant reaches maturity; hence the flowering period covers a period of from 10 to 12 weeks, as compared to a flowering period of from 4 to 6 weeks, which is usual for the biennial types under similar conditions.

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[1] Contribution from the Division of Forage Plants, Dominion Experimental Farms, Department of Agriculture, Ottawa, Canada.
[2] Agrostologist Specialist.
[3] Research Assistant.

FIGURE 1. A seed increase plot of annual dwarf branching white blossom sweet clover.

FIGURE 2. A single plant of annual dwarf branching, white blossom sweet clover, *M. alba*, showing the much branched, fine stemmed leafy type of growth.

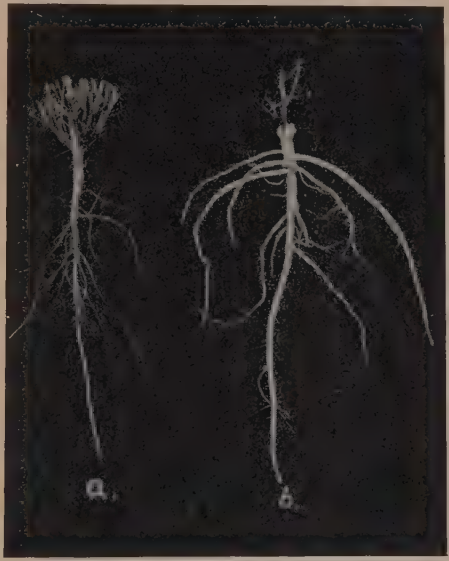

FIGURE 3. Roots of white blossom sweet clover, showing crown branching and absence of crown buds on the annual dwarf branching type (a) and the single stem from the first year's growth and well developed crown buds on the biennial type (b).

The leaves, flowers, pods and seeds are indistinguishable from those of the common biennial forms of *M. alba*. The crown of the plant branches to form from 7 to 18 stems and these in turn branch and rebranch at short intervals near the base to produce a very fine-stemmed bunch-type plant. Unlike the biennial types, the plant grows over a fairly long period and maintains a high percentage of leaf long after seeds have matured from the earlier flowers. This leafy condition continues often until mid-September, when the whole plant usually shows signs of maturing.

Comparison with the Hubam Variety

The data given in Table 1 were obtained from plants of the dwarf branching annual and Hubam, grown under similar conditions at Saskatoon during the past three years.

TABLE 1

——	Dwarf branching annual	Hubam
Date of beginning to flower	July 2 to July 10	July 28 to Aug. 6
Length of flowering period	10 to 12 weeks	5 to 7 weeks
Production of mature seed	Abundance	Very little
Height	2′ 8″ to 3′ 11″	2′ 8″ to 4′ 3″
Leafiness	Heavily leaved	Sparsely leaved
No. of stems per plant (arising from crown)	10 to 18	1

In habit of growth both are annual, but the two plants show striking differences in several important characteristics. The much branched crown and numerous fine leafy stems of the dwarf branching annual contrast strongly with the sparsely leaved, single branched stem of the Hubam variety. The earlier flowering and longer flowering period of the dwarf branching annual makes it of greater value for bee pasture. Due to the earlier maturity, this plant produces an abundance of seed, whereas little or sometimes no mature seed has been obtained from the Hubam variety under similar conditions at Saskatoon.

Possible Uses for the Dwarf Branching Annual

Sufficient data are not yet available to permit an accurate estimate of the agricultural value of this plant. The characteristics of the plant, however, indicate that it may be of value for pasture purposes, particularly for late summer pasture, since it retains its leaves until early fall. The plant appears to offer greatest possibilities for bee pasture purposes. The long flowering period, which continues for several weeks after the biennial sweet clovers have completed flowering, should serve to provide bee pasturage at a season when there is normally a scarcity of nectar bearing plants. Beekeepers who have grown the annual dwarf branching plant state that the bees work the flowers heavily during the entire blossoming period.

As an orchard crop and as a green manure crop, the annual dwarf branching sweet clover may be of value. Being an annual crop, it may be safely plowed in the fall of the year of seeding, whereas the biennial sweet clovers often renew growth the following spring, when plowed down in the fall of the first year.

Inheritance of the Annual Habit

The annual dwarf branching strain was crossed with the common biennial white flowered sweet clover and 21 seeds were obtained. Nineteen of these produced annual plants similar to the male parent. Two produced biennial plants like the female parent and apparently arose from self-pollination. Self-fertilized seeds were obtained from each of the hybrid plants and 19 F_2 progenies, totalling 1272 plants, were grown. Each F_2 progeny was examined and classified on the basis of annual or biennial type. In the classification of this material, it was noted that certain plants which blossomed in the first year were much later in flowering than others; hence classification was based upon the presence or absence of crown or resting buds, as well as upon flowering habit. The data obtained are shown in Table 2.

TABLE 2.—GOODNESS-OF-FIT TEST, BY MEANS OF X^2 DISTRIBUTION, APPLIED TO 19 F_2 FAMILIES WHICH SEGREGATED FOR ANNUAL AND BIENNIAL HABIT OF GROWTH

Plant type	O	C	O − C	$(O - C)^2$	$\frac{(O - C)^2}{C}$
A	118	115.50	2.50	6.2500	0.054112
B	36	38.50	2.50	6.2500	0.162337
A	99	98.25	0.75	0.5625	0.005725
B	32	32.75	0.75	0.5625	0.017175
A	102	105.75	3.75	14.0625	0.132987
B	39	35.25	3.75	14.0625	0.398936
A	13	15.00	2.00	4.0000	0.266667
B	7	5.00	2.00	4.0000	0.800000
A	37	35.50	2.50	6.2500	0.181159
B	9	11.50	2.50	6.2500	0.543478
A	13	16.50	3.50	12.2500	0.742424
B	9	5.50	3.50	12.2500	2.222727
A	15	15.00	0.00	0.0000	0.000000
B	5	5.00	0.00	0.0000	0.000000
A	48	47.25	0.75	0.5625	0.011905
B	15	15.75	0.75	0.5625	0.035714
A	18	15.00	3.00	9.0000	0.600000
B	2	5.00	3.00	9.0000	1.800000
A	33	33.75	0.75	0.5625	0.016667
B	12	11.25	0.75	0.5625	0.050000
A	12	14.25	2.25	5.0625	0.355263
B	7	4.75	2.25	5.0625	1.065789
A	45	48.00	3.00	9.0000	0.187500
B	19	16.00	3.00	9.0000	0.562500
A	51	53.25	2.25	5.0625	0.095070
B	20	17.75	2.25	5.0625	0.285211
A	42	43.50	1.50	2.2500	0.051724
B	16	14.50	1.50	2.2500	0.155172
A	123	119.25	3.75	14.0625	0.117924
B	36	39.75	3.75	14.0625	0.353773
A	64	63.75	0.25	0.0625	0.000980
B	21	21.25	0.25	0.0625	0.002941
A	18	16.50	1.50	2.2500	0.163364
B	4	5.50	1.50	2.2500	0.409090
A	65	66.75	1.75	3.0625	0.045880
B	24	22.25	1.75	3.0625	0.137640
A	33	32.25	0.75	0.5625	0.071442
B	10	10.75	0.75	0.5625	0.052325

$N = 19$ $X^2 = 12.074592$ $P =$ Between 0.8 and 0.9

These data were tested for goodness of fit on the basis of a 3 : 1 segregation, both individually and collectively, by means of the X^2 distribution; X^2 for the 0.05 point and one degree of freedom is 3.841, which is greater than the X^2 value obtained for any one of the F_2 progenies. The total X^2 for the 19 progenies is 12.0746. The corresponding P value for $N = 19$ is between 0.8 and 0.9, which may be interpreted to mean that deviations as great or greater than the observed could be expected more than 80 or 90 times in 100 trials on the basis of random sampling. This is a very close fit and indicates that the annual habit is inherited as a simple dominant to the biennial habit in crosses between the annual dwarf branching type and the common biennial type of *M. alba*. This corresponds with the results obtained by Smith (6) and Clarke (2) in studies conducted on the inheritance of the annual character in *M. alba*.

Origin of the Dwarf Branching Annual

This plant occurred suddenly in a dwarf branching biennial line which had been inbred for several generations. Only one variety of annual white blossom sweet clover, Hubam, had been included in our field trials prior to the appearance of this plant. Since the Hubam variety is of the common type of growth, the F_1 plant derived from a cross between it and the dwarf branching biennial would be expected to exhibit the common type of growth also, as shown by Kirk (4, 5), Elders (3), Clarke (1) and Stevenson (7). Since this new annual selection was of the dwarf branching type and since succeeding generations failed to show any tendency to segregate for type of growth, it is evident that the dwarf branching annual did not arise from a natural cross.

Reciprocal crosses were made between the Hubam variety and the annual dwarf branching selection. All of the F_1 plants were annual in habit of growth and no segregation for annual and biennial habit occurred in the F_2 progenies. These results indicate that both of the parents used in this cross possess the same dominant factor for the annual habit. From these data it is evident also that the two dominant mutations must have occurred independently.

SUMMARY

1. An annual plant of the dwarf branching type appeared spontaneously in a line of biennial dwarf branching sweet clover, *M. alba*.

2. The agricultural possibilities of this production have not been fully investigated but it is believed that it may be of value as a bee pasture plant.

3. In crosses with the common biennial, white blossom sweet clover, the annual habit was shown to behave as a simple dominant to the biennial. F_2 progenies from these crosses gave 3 : 1 segregations for annual and biennial habit of growth.

4. Evidence is submitted to show that this new annual arose as a mutation.

5. Results from reciprocal crosses between the dwarf branching annual and Hubam indicate that both plants possess the same dominant factor for the annual habit.

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BOOK REVIEW

SMITH, KENNETH—A Text Book of Plant Virus Diseases. J. & A. Churchill Ltd., 104 Gloucester Place, Portland Square, London.

The *Textbook of Plant Virus Diseases* by Dr. Kenneth Smith of Cambridge University, England, (J. & A. Churchill Ltd., 1937) is a timely addition to the literature of plant pathology. Owing to the multiplicity of papers that have been published during recent years describing plant viruses and virus diseases, plant pathologists have found it difficult to decide whether viruses discovered locally have not been studied and described already elsewhere. Smith's textbook brings together all the principal descriptions of plant viruses and virus diseases in a systematic manner based upon the virus nomenclature scheme suggested by Dr. James Johnson of Wisconsin at the last International Botanical Conference in Amsterdam. The viruses are given the generic name of a host and arabic numerals to indicate distinct types and letters in addition where distinct strains of a major type are described. This method preserves the continuity of current practice, *e.g.*, "Nicotiana virus 1A" and "1B" represent two strains of "Johnson's Tobacco virus 1." The generic name chosen represents the host upon which the effect of the viruses was first described or upon which subsequent descriptions of virus symptoms were more adequate. Owing to the support already given this scheme of nomenclature by both American and European workers, the publication of this textbook will tend to establish order in the chaotic condition of the virus literature with respect to nomenclature.

Very few descriptions of plant viruses have escaped review in chapters I to VII inclusive. Dr. Smith is fully aware that he has given arabic numbers to signify distinctiveness to viruses that later may be proven to be closely related strains of the same basic type. Already, in spite of the limitations of serological methods in virus classification, relationships have been established by this method between plant viruses formerly considered distinct.

The description of the insects involved in virus transmission and their life histories in chapter VIII serves to focus attention upon insects as vectors of virus diseases, a field that is a challenge to scientists. In spite of the highly infectious character of "Solanum Virus 1" as judged by plant juice transfers and the fact that the majority of European and practically all American varieties of potatoes are infected, no one has secured satisfactory evidence that this virus is transmitted from plant to plant by thrips or other insects.

The final chapter deals with a large group of plant species that exhibit chlorotic or other symptoms that suggest virus infection but wherein the infective character of the disease has not been proven.

A three-column appendix of 37 pages is included to assist students in the diagnosis of virus diseases. All common hosts are listed alphabetically opposite brief descriptions of the diseases to which they are susceptible and the names of the viruses involved.

—W. NEWTON.